



ARTEMIS

Artemis I PFAR

Introduction/Logistics

July 19, 2023

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Jim Turner/PFAR Secretariat

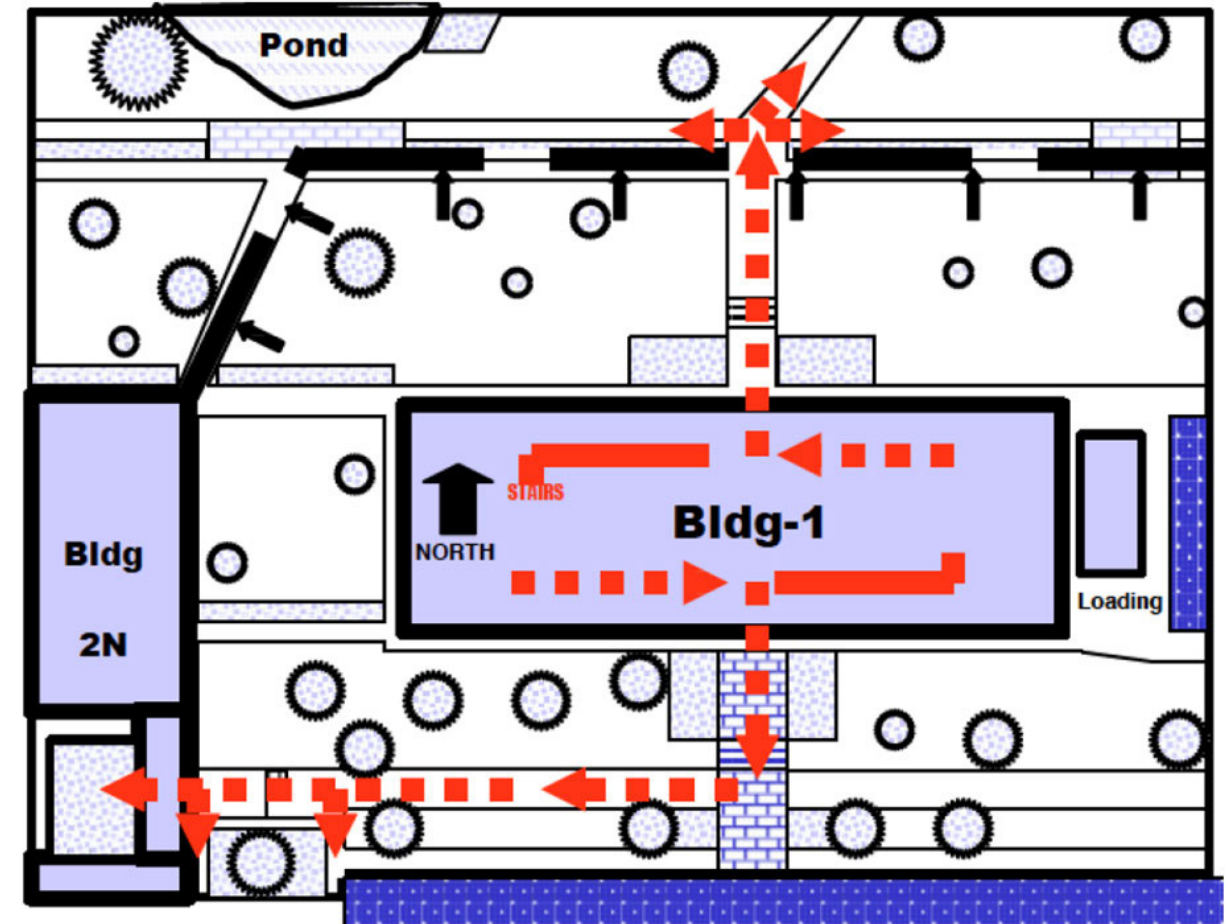
Artemis I PFAR Logistics – Safety



Fire Drill Protocol:

- Exit via stairs at the end of the hall
- Meet in assembly area per Map

Evacuation Routes and Assembly Area Map



Artemis I PFAR Logistics – Reminders



Attendance: Reminder to sign in with Review Team in the corner if have not already. Remote participants in overflow here at JSC, MSFC, and KSC, in addition to Teams participants.

Online Participation: For those online, reminder to mute mics when not speaking. Select *6 to unmute first if dialed in via CR phone.

Presenters/Speakers: Presenter spots at the end of the table. No ceiling mics, so come to the table if you need to speak.

Hospitality: Info. sheets on doors with where to get coffee, snacks, and lunch information.

Questions: Need help? Send a note to the Review Team mailbox: jsc-esi-reviews@mail.nasa.gov.



Artemis I PFAR – Agenda Logistics/Export



- **CSA Approved**
 - All topics (main charts) have been cleared for CSA attendance.
- **ESA Approved**
 - ESA will participate for the start of Day 2 – Orion (International Section) for ESM-related content.
- **Export guidance reminders on discussion restrictions are at the table**
- **Agenda Review: [Artemis I PFAR Agenda](#)**



Artemis I PFAR (ESD 10018 Annex 3)



- **The purpose of the Artemis I Post-Flight Assessment Review (PFAR) is to ensure anomalies, lessons learned, and accomplishment of mission objectives are captured, and that impacts to downstream missions are assessed and integrated across the Enterprise.**
- **Each Program, FOD, and ESI conducted PFARs, assessing Success Criteria to ensure preparation for the Artemis I PFAR.**
- **Actions: Will be captured and reviewed during the meeting. Formal actions will be tracked through the CPIT until closed.**
- **Executive Summary and Actions will be published ~7 days following the review.**
- **PFAR Conclusion/Success Criteria Assessment: The Artemis I PFAR Success Criteria are complete or associated open work is planned for completion.**



Artemis I PFAR Board Members/Reps



Board Members		
Chair, DAA, Moon to Mars Program Office	Amit Kshatriya	In-Person
Artemis I Mission Manager	Mike Sarafin	In-Person
Moon to Mars SE&I Office (CSI)	Wayne Jermstad	In-Person
EGS Program Manager	Jeremy Parsons (S. Quinn Remote)	In-Person
Orion Program Manager	Debbie Korth/Jim Geffre	In-Person
SLS Program Manager	David Beaman (J. Honeycutt Remote)	In-Person
Flight Operations Directorate (FOD) Director	Megan Levins	In-Person
Moon to Mars Chief Engineer	John McManamen	In-Person
Moon to Mars Chief SMA Officer	George Deckert	In-Person
Chief Health and Performance Officer (CHPO)	Susan Baggerman	In-Person
Programmatic and Strategic Integration (PSI) Director	Maritza Alexander	In-Person
Moon to Mars SMA Director	Lori Childress	In-Person

Note: Artemis II crew are in training this week. Komrade will join PFAR Day 2.



Backup Information

Artemis I PFAR Entrance and Success Criteria



PFAR Entrance Criteria:

1. All In Flight Anomalies (IFA), as defined in ESD 10018, as well as those non-conformances and variances which occurred from securing the CM in the well deck through CM turnover to Orion Program, are identified and dispositioned, or have closure plans.
2. All program and ESD Documents from the mission are retained in the CM system and are available for use for future missions.
3. All planned activities to be performed post-flight have been completed or are scheduled to be completed.
4. Problem reports, corrective action requests, post-flight anomaly records, and operations team/flight crew debriefs are captured. Include spectrum (radio frequency) interference during assessment.
5. All post-flight hardware and flight performance data evaluation reports are completed, including assessments of ESD FTOs, Mission objectives (defined in ESD 10026-EMX) and program verification and system validation reports (FOC allocations).
6. Plans for retaining assessment documentation and imaging have been made, and archival systems are in place.

PFAR Success Criteria:

1. Information required for the completion of the formal final report documenting flight performance and recommendations for future missions is available and adequate.
2. All IFAs have been adequately documented and dispositioned. Any that are still open have a closure plan.
3. The impact of IFAs on future missions have been assessed and documented.
4. Reports and other documentation have been retained for performance comparison and trending.
5. Responsible Center spectrum manager was notified of any RF spectrum interference issues.
6. Recommendations for updates to the system design, test and operations procedures, or safety inspections have been identified and a credible plan exists to incorporate the changes.





ARTEMIS

Artemis I PFAR

Artemis I Mission Overview

July 19-20, 2023

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Michael L. Sarafin
Artemis I Mission Manager

Agenda



- Artemis I Integrated Post Mission Report – Content and Structure
- As-Flown Artemis I Mission Map
- Mission Timeline: As-Flown Key Parameters
- Assessment of Mission Priorities – As Flown
- Assessment of Flight Test Objectives (FTOs) and Development Flight Test Objectives (DFTOs)
- Secondary Payloads Performance Summary
- Mission Management Significant Lessons Learned
- Artemis II Mission Liens & Threats
- Key Reference Material; Links



Artemis I Integrated Post Mission Report – Content & Structure



- ESD 20073, Artemis I Integrated Post Mission Report
 - Purpose: To provide an integrated Executive Summary of Artemis I mission from Agency FRR through recovery of the Orion CM
 - Product driven by requirement documented in Mission Integration Implementation Plan (MIIP), ESD 10018, section 5.6.13
 - Top level record on where to find all known post-mission deliverables whether they be M2M/CESD, Orion/SLS/EGS program, cross-program, MMT, external, etc products
 - Not intended to duplicate program or subsystem reports
 - Non-CUI (contains pointers on where to find CUI data)
 - Data Managed (DM) product
 - Post Mission Report available at: [CESD Documents - Common Exploration Systems Development \(CESD\) - ICE Portal \(nasa.gov\)](#)

Integrated Post Mission Report – Summary

- 1.0, Introduction
- 2.0, Mission Overview
- 3.0, SLS Overview
- 4.0, Orion Overview
- 5.0, Ground Processing Overview
- 6.0, Launch Operations Overview
- 7.0, Flight Operations Overview
- 8.0, Recovery Operations Overview
- 9.0, MMT Overview
- 10.0, Flight Test Working Group Overview
- 11.0, JETI Overview
- 12.0, ICAN Overview
- 13.0, CESD SMA Overview
- 14.0, CoFR Overview
- 15.0, Artemis II Mission Liens & Threats





A B C
CUBESATS DEPLOY
ICPS deploys 10
CubeSats total

MISSION DURATIONS:
Total: 25 days, 10 hrs
Outbound Transit: 9 days 13 hrs
DRO Stay: 6 days 0 hrs
Return Transit: 9 days 19 hrs

ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

-
- 1 LAUNCH (11/16/22)**
SLS and Orion lift off from pad 39B at Kennedy Space Center.
 - 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
 - 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
 - 4 PERIGEE RAISE MANEUVER**
 - 5 EARTH ORBIT**
Systems check with solar panel adjustments.
 - 6 TRANS LUNAR INJECTION (TLI) BURN**
Maneuver lasts for approximately 20 minutes.
 - 7 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
ICPS commits Orion to moon at TLI.
 - 8 OUTBOUND TRAJECTORY CORRECTION BURNS**
As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
 - 9 OUTBOUND POWERED FLYBY**
105.5 miles from the Moon; targets DRO insertion.
 - 10 LUNAR ORBIT INSERTION**
Enter Distant Retrograde Orbit.
 - 11 DISTANT RETROGRADE ORBIT**
Perform a half revolution (6 day duration) in the orbit 43,730 miles from the surface of the Moon.
 - 12 DRO DEPARTURE**
Leave DRO and start return to Earth.
 - 13 RETURN POWERED FLYBY**
RPF burn prep and return coast to Earth initiated. Closest approach in middle of burn, 81 miles.
 - 14 RETURN TRANSIT**
Return Trajectory Correction burns as necessary to aim for Earth's atmosphere.
 - 15 CREW MODULE SEPARATION FROM SERVICE MODULE**
 - 16 ENTRY INTERFACE**
Enter Earth's atmosphere.
 - 17 SPLASHDOWN (12/11/22)**
Pacific Ocean landing within view of the U.S. Navy recovery ship.

Mission Timeline: As-Flown Key Parameters

Mission Parameter	Actuals	
	Day, Time (EST)	MET (dd/hh:mm:ss)
Launch Time	11/16/2022, 1:47:44 AM EST	00:00:00
Flight Azimuth	78.3 deg	
Lighting Percent	0% (Night)	
Secondary Payloads Deploy Times	ArgoMoon - 0/03:45:18	LunaH-Map - 0/05:37:18
	BioSentinel - 0/03:41:18	LunIR - 0/06:07:18
	CuSP - 0/08:00:18	NEA Scout - 0/05:10:18
	EQUULEUS - 0/03:39:18	(Predicted time, no contact established)
	Lunar IceCube - 0/03:44:18 (Predicted time, no contact established)	OMOTENASHI - 0/03:42:18
		Team Miles - 0/07:02:18
TLI-OPF Duration (dt)	5/04:27:05	

Mission Event	Actuals	
	Day, Time (EST)	MET (dd/hh:mm:ss)
Outbound Powered Flyby (TIG)	11/21/22, 7:44:14 AM	5/05:56:30
OPF to DRI Duration (dt)	4/09:08:14	
DRO Insertion (TIG)	11/25/2022 4:52:28 PM	9/15:04:44
DRO Inclination	None	
DRO Duration (dt)	6/00:01:28	
DRO Departure (TIG)	12/1/2022 4:53:57 PM	15/15:06:13
DRD to RPF Duration (dt)	3/18:49:24	
Return Powered Flyby (TIG)	12/5/2022 11:43:20 AM	19/09:55:36
RPF to EI Duration (dt)	6/00:36:54	
Entry Interface	12/11/2022 12:20:14 PM	25/10:32:30
Splashdown Time & Lighting	12/11/2022 12:40:13 PM 3.13 hours after sunrise	25/10:52:29

Assessment of Mission Priorities – As Flown

1. Demonstrate Orion heatshield at lunar re-entry conditions (Accomplished using a skip re-entry)

- ✓ Validate required system performance that is mandatory to support crewed missions, which can only be achieved in actual flight environment
 - *Pending Issue Resolution Team (IRT) establishment of root cause and corrective actions on heatshield char loss during CM re-entry*
- ✓ Demonstrate Space Launch System (SLS) ascent and launch vehicle operations including ascent separation events

2. Operate Systems in Flight Environment

- ✓ Demonstrate Orion deep space environmental performance, communications, propulsion, and navigation systems
- ✓ Demonstrate Exploration Ground Systems (EGS) and day of launch operations and support of EGS recovery forces if possible
- ✓ Demonstrate Flight Operations management, execution, network management of Near Earth Network (NEN), Space Network (SN), and Deep Space Network (DSN) and facilities support systems

3. Retrieve Spacecraft

- ✓ Position assets and demonstrate Orion crew module recovery when conditions maintain Orion within certified hardware capability and nominal operating limits
- ✓ Retrieve Orion crew module, accepting risk of vehicle structure and Thermal Protection System (TPS) damage, when conditions are expected to exceed certified hardware capabilities or when the crew module does not land at the nominal end of mission location

KEY

✓ = Achieved, except
where noted otherwise

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Assessment of Mission Priorities – As Flown

4. Complete Remaining Objectives

- ✓ Provide lighted landing to support imagery collection during the entry, descent, and landing sequence
- ✓ Complete additional time in deep space for system trending and analysis
- ✓ Conduct optical navigation certification
- ✓ Demonstrate redundant systems and downmode capability to the extent practical
- ✓ Perform remaining Exploration Systems Development (ESD) and Program Flight Test Objectives (FTOs) and Program specific activities
 - *Most ESD FTOs fully achieved (11 out of 12) - see 'Assessment of FTOs and DFTOs' for further details*
 - *Most Program FTOs and DFTOs fully or partially achieved - see 'Assessment of FTOs and DFTOs' for further details*
 - *Performed an additional 21 DFTOs added during real-time operations*
- ✓ Deploy SLS Orion Spacecraft Adapter (OSA) secondary payloads
 - *Communications established with 6 out of 10 Cubesats; see 'Secondary Payloads Flight Performance' for further details*
- ✓ Support NASA Office of Communications (OCOM) High Priority Public Affairs outreach activities
 - *Achieved majority of OCOM Imagery objectives*
 - *Did not capture scene #14 on Flight Day 3 (still images of Earth); scene #32 on Flight Day 26 (CM/SM separation)*
- ✓ Support Crew Interface Technology (CIT) Payload activities
- ✓ Support remaining NASA OCOM outreach activities

KEY

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Assessment of ESD FTOs – As Flown

ESD Flight Test Objective Summary (Artemis I)

- ✓ ESD-FTO-12, Demonstrate Crew Module safing and recovery operations post-landing – *Fully Achieved*
- ✓ ESD-FTO-14, Obtain the induced environments data during all appropriate flight phases – *Fully Achieved*
- ✓ ESD-FTO-15, Determine performance of critical events for all flight phases – *Fully Achieved*
- ✓ ESD-FTO-16, Determine structural integrity of the integrated vehicle during all flight phases and critical events – *Fully Achieved*
- ✓ ESD-FTO-17, Demonstrate the Communications, Network, and Tracking capabilities during all flight phases – *Fully Achieved*
 - *Several unplanned communication losses experienced while using SCan assets (NEN, DSN)*
 - *Failure Review Board (FRB) investigation of Goldstone DSN site-wide outage complete; corrective actions in-work*
- ✓ ESD-FTO-20, Determine entry, descent, and landing integrated vehicle systems performance and critical events – *Fully Achieved*
- ✓ ESD-FTO-23, Determine performance and delivery of Orion to specified insertion point destination orbit and then return to Earth trajectory to enable BEO missions – *Fully Achieved*
- ✓ ESD-FTO-24, Determine control and control margin of integrated vehicle during all flight phases – *Fully Achieved*
- ✓ ESD-FTO-26, Demonstrate human-systems integration capability of the space systems during conditions imposed by flight environments and mission timelines – *Fully Achieved*
- ✓ ESD-FTO-27, Determine safe disposal of jettisoned objects from integrated vehicle during all flight phases – *Fully Achieved*
- ✓ ESD-FTO-28, Identify any potential liftoff, ascent or separation debris capable of capture with available imagery – *Partially Achieved*
 - *Issues Resolution Team (IRT) established to investigate root cause, corrective actions, and mitigations associated with loss of some FTO imagery during launch and ascent due to camera failures and/or incorrect camera set-up.*
- ✓ ESD-FTO-29, Characterize Orion Integrated systems performance post separation from ICPS until CM/SM separation – *Fully Achieved*

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KEY

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Assessment of Program-Specific FTOs and DFTOs – As Flown



- **Orion FTOs – 123 total**

- ✓ Fully Achieved: 102 FTOs
- ✓ Partially Achieved: 19 FTOs
 - 16 of 19 Partially Achieved FTOs currently planned for Artemis II
 - Partially Achieved FTOs that are not planned for Artemis II (qty: 3) are due to sensors already planned/installed on the next spacecraft
- 2 FTOs not achieved – Forward Bay Cover (FBC) & parachutes sank into the ocean before recovery could be attempted
 - EM1-108 – Determine performance of the Forward Bay Cover Parachutes
 - EM1-193 – Demonstrate nominal end-of-mission main parachute & FBC recovery
 - Both currently planned for Artemis II

- **Orion DFTOs – 35 total; 14 Planned and 21 Real-Time**

- Real-Time DFTOs were not part of baseline established at FRR; MMT reviewed and approved these during the mission
- ✓ Fully Achieved: 33 DFTOs (includes 21 Real-Time DFTOs)
- ✓ Partially Achieved: 2 DFTOs
 - DFTO-EM1-19, Demonstrate SAT Mode as onboard comm recovery mechanism – Missing RPM data prevented full analysis
 - R/T DFTO-EM1-20, SAW Angle Influence on ATCS – Did not reach equilibrium of temp and mix valve position

KEY

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where noted otherwise

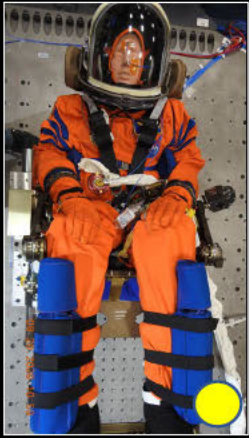
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Artemis I Payload Summary – As Flown



Moonikin Campos

Male-bodied manikin previously used in Orion vibration tests. Campos occupied the commander's seat inside and wore an Orion Crew Survival System suit



Radiation Sensors

Three types of sensors, including the ESA Active Dosimeters, Hybrid Electronic Radiation Assessor, and the Radiation Area Monitor.



MARE

Radiation shielding Personal Protection Equipment (radiation vest) for astronauts.



Crew Interface Technology (CIT) Payload (aka Callisto)
Created an interactive experience between Orion and the public during the mission



Bio-Experiment-1

Battery-powered life sciences payload for biology research beyond low-Earth orbit (LEO)

KEY: Mission Objective Outcome



Accomplished



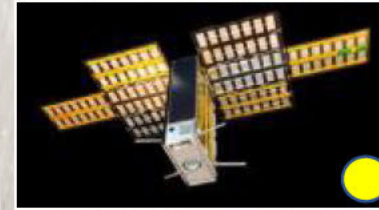
Partially Accomplished



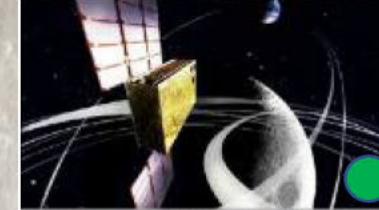
Not Accomplished



ArgoMoon



LunaH-Map



EQUULEUS



OMOTENASHI



LunIR



Near-Earth Asteroid Scout (NEA Scout)



Lunar IceCube



BioSentinel



Team Miles



CuSP

Secondary Payloads – Cubesat Performance Summary



- Deployed 10 Secondary Payloads (SPLs)/CubeSats from the SLS Orion Spacecraft Adapter (OSA)
 - Cubesats historically have high failure rate due to low cost/high reward, combined with “do no harm” approach to rideshare mission(s)
- Payloads that established communication and met a majority of their planned secondary mission objectives:
 - EQUilibriUm Luna-Earth point 6U Spacecraft (EQUULEUS) – met mission success/demonstrated low energy Earth-Moon L1 transfer
 - BioSentinel – met mission success/gathered radiation data
- Payloads that established communication and met some mission objectives:
 - Lunar polar Hydrogen Mapper (LunaH-Map) – propulsion valve stuck; other systems OK
 - Outstanding MOon TEchnologies demo by NAno Semi-Hard Impactor (OMOTENASHI) – initial contact, terminal spin; power negative, loss of signal (LOS)
 - ArgoMoon – Obtained some imagery of Earth/Moon, declared spacecraft emergency on 11/29/22 with LOS
 - LunIR – obtained Day 1 telemetry; LOS thereafter
- Payloads that did not establish communications:
 - Lunar Ice Cube – lost contact after initial commanding; efforts unable to detect carrier signal/LOS
 - Near Earth Asteroid Scout (NEA Scout) – no telemetry received
 - Cubesat to Study Solar Particles (CuSP) – deployed solar arrays/detumbled; LOS after three reboots and battery anomaly
 - Team Miles – fast roll rate; good for power production but bad for communication/weak signal
- SCA_N established communications as best as possible with data given from Payload Developers
 - SCA_N ended up providing more DSN time than planned pre-mission; given relative priority and assets available

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Secondary Payloads – Cubesat Performance Summary



- SLS SPL Battery Charging Opportunities
 - On three occasions (in February, July, and October 2022), pre-flight battery charging was offered in the VAB for the SLS OSA Avionics Unit and the CubeSats that met the safety and interface requirements for integrated battery charging
 - Five (5) CubeSats chose to take advantage of one or more of the charging opportunities including:
 - EQUULEUS
 - BioSentinel
 - ArgoMoon
 - NEA Scout
 - OMOTENASHI
- Deployment signal sent from ICPS to the Secondary Payload Avionics Unit in Orion Spacecraft Adapter (OSA) to deploy
 - Initiate the pre-loaded timing skit for deployment of the payloads at their designated times/bus stops
 - Avionics Unit was activated by the ICPS at 12,255.06 sec MET, which corresponds to 10:11.58.981 UTC
- SLS completed all mission objectives in relation to SPLs with scope ending at deployment + 15 seconds
 - M2M is not responsible for CubeSat mission success; provided delivery of payload to selected deploy location(s)
- For additional information on individual cubesat outcome and their ability to meet their objectives, refer to the individual payload developers and/or their sponsoring organization

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Secondary Payloads Performance Summary

- **Orion Payloads (in-cabin)**

- Crew Interface Technology (CIT) Payload or Callisto
 - Activated once ~daily; performed numerous data takes successfully
- Matroshka Astrorad Radiation Experiment (MARE)
 - Radiation shielding Personal Protection Equipment (radiation vest) for Astronauts
 - Two Matroshka phantoms instrumented with radiation detectors with vest on only one phantom
- ESA Active Dosimeters (EAD) Payload
 - Flew 5 dosimeters to continuously gather radiation data
- Biology Experiment-1 (BIOEXPT-1) Payload
 - Flew 2 payload bags with autonomous biological research
 - Early retrieval from Orion was performed to protect biological samples once at Naval Base San Diego
- Moonikin Campos
 - Data losses on vibration sensors

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Mission Mgmt Significant Lessons Learned

Lessons Learned Description	Mitigations Utilized
1) Train both a Prime & Alternate for each MMT position	- Planned ahead and experienced attrition due to illness (COVID), family issues, personnel reassignment and/or job changes, etc. - Gave opportunity to others to gain mission experience, provide relief to prime member during mission.
2) Use training to flesh out MMT logistics, distribution lists, facility access, etc.	- Established template, process, roles for large distributed team across multiple centers and mission phases. - Enabled quick and efficient communication, action, issue tracking, and issue resolution across entire team.

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Mission Mgmt Significant Lessons Learned

Lessons Learned Description	Forward Action
3) Anomaly/Issue Reporting to MMT at the MMT meetings should be streamlined Most issues reported to the MMT required no action and no risk acceptance, so communication of situational awareness were only items that could be streamlined (eg, SAW camera controller funny recovered with reset).	- Update MMT Ops Plan, SE&I Ops Plan and S&MA Plan. - Agendas are good (FOD, then MER, then Programs, SE&I and S&MA to review issues, Tas); however, some observations do not warrant being discussed multiple times (could be up to 4 times per agenda). - Issue reporting should be streamlined across the agenda based on significant of issue, impact to mission, need for MMT decision (eg, out of family, mission impact, decision drivers, etc).
4) Export Control processes during mission need to be consistent, streamlined, drive less overhead - I/T tools used during Artemis I required MMT Secretariat team to 'mirror' the MMT portal to share MMT agendas, minutes, etc with ESA just to share basic MMT meeting information - ESA member of MMT was required to have a NASA escort inside the LCC, but not inside the MCC facility	- Board members (including ESA/foreign nationals, in some cases) need to be able to see data to make risk-informed decisions. - Single point failures exist in current export control process; need back-ups/ alternates across multi-center and multi-program enterprise. - Export control processes should aim to standardized guidance, requirements, training across-the-board to make export control processes consistent and repeatable regardless of program, center, or ECR/reviewer.

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Mission Mgmt Significant Lessons Learned

Lessons Learned Description	Forward Action
5) Additional mission specific training with MMT would be beneficial	- Update MMT Training Plan (which sims to perform, # of sims); MMT Ops Plan (Appendix with Cert requirements) - Multiple MMT members commented on need for additional training for either specific flight phases or to better train alternate team member. - Requests driven by need to be more familiar with either the flight phase (Launch Countdown, Landing Site Selection/Entry) and/or facility (LCC, Firing Room ops on headset) and/or processes (CHITs, etc)
6) Expand communications for MMT members to include items that may transition between Daily Board and MMT and/or back (as appropriate) from roll-out to launch (or roll-back complete) - Some similarities between Daily Board and MMT roles. However, attendance, set-up, and issues differ. There's also a handoff, different distributions lists, different meeting portals and meeting support. - Due to hurricanes, hydrogen leaks, technical issues at pad, the path to Artemis I launch was not always crystal clear given multiple possible outcomes, need for interim steps to determine course of action (eg, Launch attempt #2 TSMU LH2 leak at 8-in QD, Range Safety waiver on FTS batteries, roll-back due to Hurricane Ian)	- Daily Board starts during KSC integrated ground ops (many months before launch) and hands over to MMT at L-2 days. Hand back to Daily Board occurs at end of mission (or roll-back) per the MIIP. - Recommendation is to overcommunicate by doubling up on MMT and Daily Board communications starting at vehicle roll-out to pad, plus add pointers from/to Daily Board portal and MMT portal, plus add calendar of meetings once inside roll-out period to ensure clarity in which program meeting is governing decisions and accepting risks. - Update MMT Ops Plan, GSDO-PLN-1195 (PALSGO), MMT and Daily Board portals and communication emails/notices (Page 3 of 3)

Artemis II Mission Liens & Threats



Issue #	Description	Lead(s)	ECD
A1-1	Launch Imagery Issues – Over-exposure, field-of-view out of alignment, camera fog, scan lines, etc	Charlie Blackwell-Thompson (EGS); Joe Voor (JETI)	Pending ECD 09/30/2023
A1-2	Launch Loads and Environments – Induced loads differed from model during tower clear	Anton Kiriwas (EGS)	Pending Environments IDM Completed 6/30/23 CR Approval ECD 9/30
A1-3	Mobile Launcher 1 (ML-1) post mission – Repair, refurbishment & hardening	Cliff Lanham (EGS)	Pending (Driven by start of stacking) ECD 2/21/2024
A1-4	Launch Foreign Object Debris (FOD) – Debris sources, assessment, and mitigation	Charlie Blackwell-Thompson (EGS)	Pending ECD 2/21/2024
A1-5	Orion Crew Module Base Heatshield – Char loss investigation, ground testing, forward plan	Luis Saucedo (Orion)	ECD 3/29/24 (CUBRC test driven)
A1-6	Orion Power Conditioning & Distribution Unit (PCDU) Latching Current Limiter (LCL) – Uncommanded open occurrences, mitigation	Ed Lewandowski (Orion); Ramon Lebron (Orion); Renato Avila (Airbus)	Pending (Testing in Aug 2023) ECD 01/31/2024
A1-7	Deep Space Network (DSN) Site-Wide Outage – Assessment of 33-hr site-wide outage at Goldstone, mitigation	Jena Garrahy (SCaN); Mike Levesque (JPL)	FRB Closed COMPLETED April 2023
A1-8	CM-SM Retention & Release (R&R) Separation Bolt – unexpected condition observed post mission (<i>EMERGING</i>)	C.J. Johnson (Orion)	Pending ECD TBD

Artemis I PFAR, July 19-20, 2023

This document does not contain export-controlled information. ~~It is not approved for public release.~~



Key Reference Material; Links

- Artemis I Integrated Post Mission Report: [CESD Documents - ICE Portal \(nasa.gov\)](#)
- Artemis I Lesson Learned - ESDMD Knowledge Sharing Portal: [Artemis I Lessons Learned \(sharepoint.com\)](#)
- Mission Definition Baseline, ESD 10026-EM1, Rev T (As-Flown Revision): [CESD Documents - ICE Portal \(nasa.gov\)](#)
- Artemis I MMT Portal (meeting agenda, minutes, presentation charts): [HOME - Artemis MMT - ICE Portal \(nasa.gov\)](#)
- Artemis I Daily Board Stand-Up Notes: [Daily Stand-Up Notes - All Documents \(nasa.gov\)](#)
- APPEL “Small Steps, Giant Leaps” Podcast: <https://www.nasa.gov/mediacast/small-steps-giant-leaps-episode-101-artemis-missions>
- Artemis I SE&I Post Flight V&V Test Report: [ESD 20030 FOC Validation Report](#) (Working Draft, Version 5)
- Orion Post Flight Analysis of FTO and DFTO Report: [MPCV 72656](#)
- SLS Flight Evaluation Report, SLS-RPT-223-02: [SLS PFAR - SLS Program - ICE Portal \(nasa.gov\)](#)
- EGS Post Flight Report: [GSDO-RPT-1339 Revision Baseline, Artemis I - EGS Subsystem Performance Report](#)
- As-Flown Flight Plan: [Artemis I EFP Page](#)
- Mission Analysis & Integrated Assessments (MAIA) Mission Products (mission availability calendars, mission maps, etc): [MAIA Mission Products](#)
- ICAN: Artemis I Test Products documented in [ESD 10031 Anx01](#); ICAN PFAR information documented in [ESD 20070](#)
- JETI Imagery Post Flight Report: [ESD 20055-01](#)

Backup

Artemis I DFTOs



DFTO Number	DFTO Name
DFTO EM1-01	Exercise Orion ESM ATCS Radiator Loop Pump flow Control Mode During Artemis I Flight
DFTO EM1-02	Prescribed RCS Firings on Artemis I MPCV Crew Module Re-Entry
DFTO EM1-03	Artemis I Corrosion Monitoring and Sensing DFTO
DFTO-EM1-10	Star Tracker/IMU Alignment Sensitivity to Thermal Variations - High Priority
DFTO-EM1-10	Star Tracker/IMU Alignment Sensitivity to Thermal Variations - Lower Priority
DFTO-EM1-11	Long Range Bearing Opportunity
DFTO-EM1-12	OpNav Camera Imagery - High Priority
DFTO-EM1-12	OpNav Camera Imagery - Lower Priority
DFTO-EM1-12	OpNav Camera Imagery - Flybys
DFTO-EM1-13	SM RCS Check-Out of ARTEMIS II 28 msec Minimum Firing Duration
DFTO-EM1-14	Low-G Axial Slosh Characterization
DFTO-EM1-15	Characterize SAW Heating due to Plume during RCS Firings
DFTO-EM1-16	Quantify Contribution of Solar Glint from CM Backshell to Solar Array Section Output during Artemis I Flight
DFTO-EM1-17	Post-Landing Ammonia Boiler Restart DFTO
DFTO-EM1-18	Solar Array Wing (SAW) Camera Wi-Fi Characterization DFTO
DFTO-EM1-19	SAT Mode DFTO
DFTO-EM1-20	Integrated SARSAT Functionality DFTO



Artemis I Real Time DFTOs



Real Time DFTO Number	Real Time DFTO Name
R/T DFTO-EM1-1	Longer Duration +X Burn (Chit 56)
R/T DFTO-EM1-2	Aux Radiative Heating Effects on SAW During Longer Duration +X Burn (Chit 56)
R/T DFTO-EM1-3	ESM +/- Y RCS Feedline Heater Setpoint Reduction (Chit 64)
R/T DFTO-EM1-4	Disable ESM MMH Guard Heaters (Chit 67)
R/T DFTO-EM1-5	Thermal Characterization within Full TtS Box (Chit 66)
R/T DFTO-EM1-6	Explore 3/10 Hr Rule Attitudes Not used in ST DFTO (Chit 63)
R/T DFTO-EM1-7	Constrain Attitude to Keep +Z of ESM in Shadow (Chit 66)
R/T DFTO-EM1-8	OMSe Pure Tail-to-Sun with Tight and Loose Deadbands (Chit 88)
R/T DFTO-EM1-9	NOT PERFORMED - Perform MON-2 Branch Valve Cycles (Withdrawn after submittal)
R/T DFTO-EM1-10	MON and MMH PCA Branch 2 Leak Check (Chit 89)
R/T DFTO-EM1-11	Fly Portion of the Mission in 3DOF (Chit 49)
R/T DFTO-EM1-12	Staggered OMSe Purge (Chit 81)
R/T DFTO-EM1-13	Test High-Rate Attitude Maneuver (Chit 53)
R/T DFTO-EM1-14	Perform Mixed String RCS Firings (Chit 76)
R/T DFTO-EM1-15	Additional Run of Exercise Orion ESM ATCS Radiator Loop Pump Flow Control Mode During Artemis I Flight (FN 326D)
R/T DFTO-EM1-16	LRS Heater Setpoints (Chit 12)
R/T DFTO-EM1-17	Assess Change in OpNav Camera Alignment/Distortion During ST Thermal DFTO #5 (Chit 52)
R/T DFTO-EM1-18	CM Propulsion Propellant Tank Heater Set Point Change for PVT Algorithm Performance Response Eval (Chit 50)
R/T DFTO-EM1-19	Confirm min of two PCDU Umbilical LCLs can support high vehicle electrical load (Chit 44) during quiescent ops
R/T DFTO-EM1-20	SAW IG Angle Influence on ATCS Performance (Chit 87)
R/T DFTO-EM1-21	Repeat Modal Survey (Chit 51)
R/T DFTO-EM1-22	Request for DSN comm latency assessment DFTO (CHIT 78)

Artemis I Flight, July 13-29, 2020

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Payloads ITT Lessons Learned

Prgm	Issue	Impact	Recommendation
Orion	Work to baseline (LRD) not consistently updated across Programs	- Working to schedules that are not real often driving costs on payload teams - Unnecessary technical risk due to making decisions on dates that we know are not real - Adversarial role for PD/Orion/EGS - Makes L- date dependencies difficult/impossible to plan/schedule (biological/limited life issues)	- Work to risk-informed schedule - Provide schedule change memos agency wide - Develop pad late stow capability
Orion	Need payload requirements	Lack of a parent requirement to accommodate payloads and cargo in the CM	- Orion should define a payload capability (volume, mass, power, etc.) that can be provided for each mission - Capabilities will be captured in the Orion IDD and released in a payload handbook - Address funding including use of RSAAs
Orion	EGS needs more of a logistics package, rather than a traditional Acceptance Data Package (ADP), especially for packed bags	Using the ADP for EGS approval is not efficient	- Recommended to EGS to consider co-developing form for PL/cargo handover - Will minimize missing data or the need for EGS to search through the ADP to locate the property data they require



ARTEMIS

Artemis I PFAR

Cross Program Systems Integration (CSI) Status

July 19-20, 2023

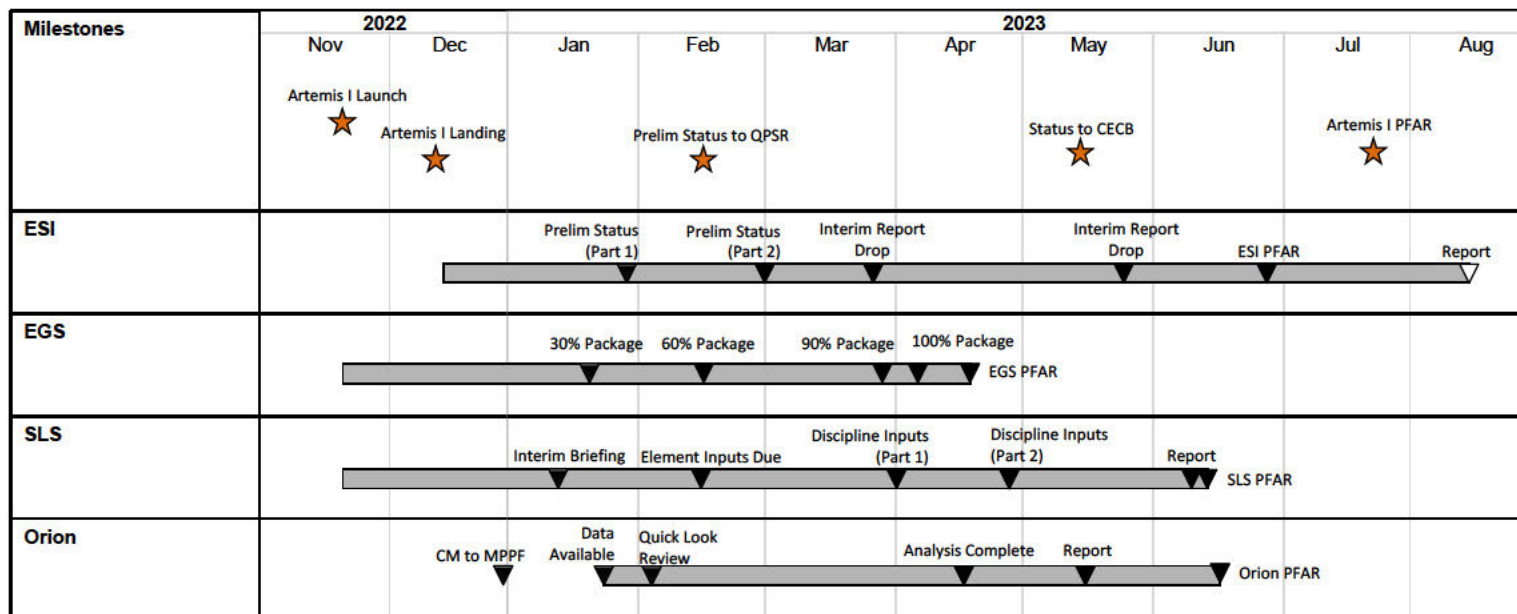
This document does not contain information which falls under the purview of the U.S. Munitions List (USML), as defined in the International Traffic in Arms Regulations (ITAR), 22 CFR 120-130, or the Export Administration Regulations (EAR), 15 CFR 730-774, and is not export controlled. This document is not intended for distribution outside of the NASA, its contractors, and International Partners. Release to the public requires approval through the appropriate NASA Release Process (e.g., FOIA, NASA STI, etc.).

Moon to Mars SE&I
Wayne Jermstad

- **Introduction**
- **Special Topics Preview**
- **SE&I Roadmap**
- **IFA Summary**
- **SE&I Discipline Summary**
- **Risks**
- **Significant Lessons Learned**
- **ESI PFAR Success Criteria Summary**
- **Backup**

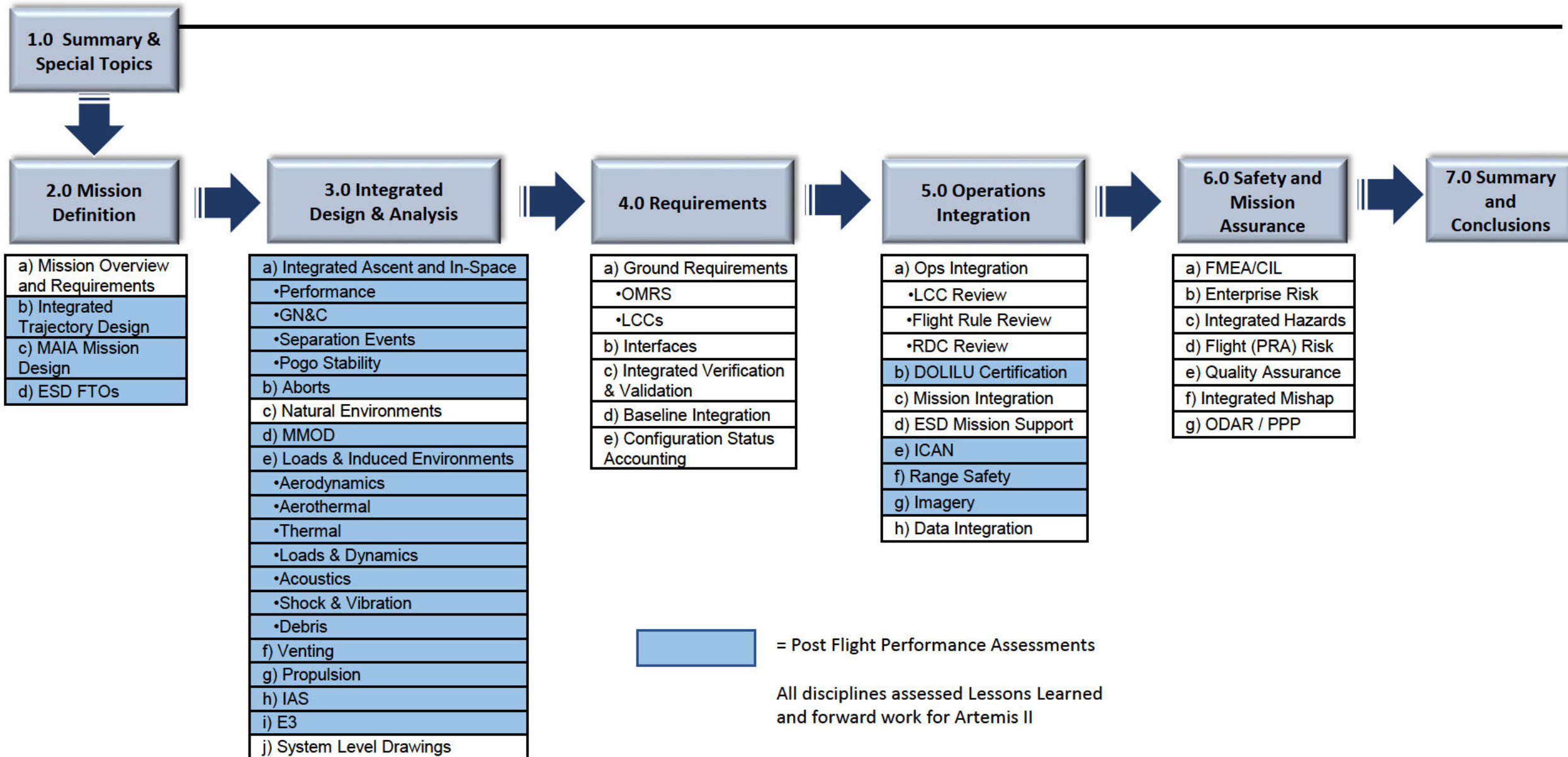
- **Previous completed PFAR activity**

- JICB post flight status 1/27/23, 3/1/23
- EGS PFAR 4/18/23
- M2M CB post flight status 5/11/23
- SLS PFAR 6/12/23
- Orion PFAR 6/15/23
- ESI PFAR 6/27-28/23



- **Artemis I PFAR entrance criteria has been assessed against ESI PFAR success criteria**
 - Most work is complete, any open work has plans in place to complete
- **SE&I is ready to support the Artemis I PFAR**

Presentation	Special Topics include:
SLS	Cryogenic Loading Attempts
	Ascent Debris-LH2/IT Flange Cracks & Liftoff Debris
	Hydrogen Leads – Ground/TSMU
	ICPS Boot
	Vehicle QD
Orion	Heatshield Char
	PCDU
	Sep Bolt
EGS	Pad Access
	Imagery Tiger Team
	Pad Damage & Debris
	Artemis I Ground Integration Process Improvements
FOD	Goldstone Site Outage - incl. rollup of SCan status going into Launch
Standalone Topic: M2M/Karika	Lessons Learned Closure Plan
Standalone Topic: HH&P/Baggerman	Integrated Radiation Monitoring



97 Total IFAs were generated during Artemis I

All were reviewed by the Baseline Integration ITT for cross program applicability
38 determined to be cross program

EGS

- 10 IFAs with 9 of those cross program
- 7 are being addressed by tiger/team or special topic
- Other 2 were fwd/aft pressure purge anomalies for ICPS, LCC violations during LCD

Orion

- 60 IFAs with 11 of those cross program
- 1 addressed by Special Topic, Debris – cork
- 4 are CP w/prox ops implications, 5 related to EGS

Flight Operations Directorate

- 8 IFAs with 5 of those cross program
- One being addressed by Special Topic (Loss of Goldstone)
- All others ICAN related

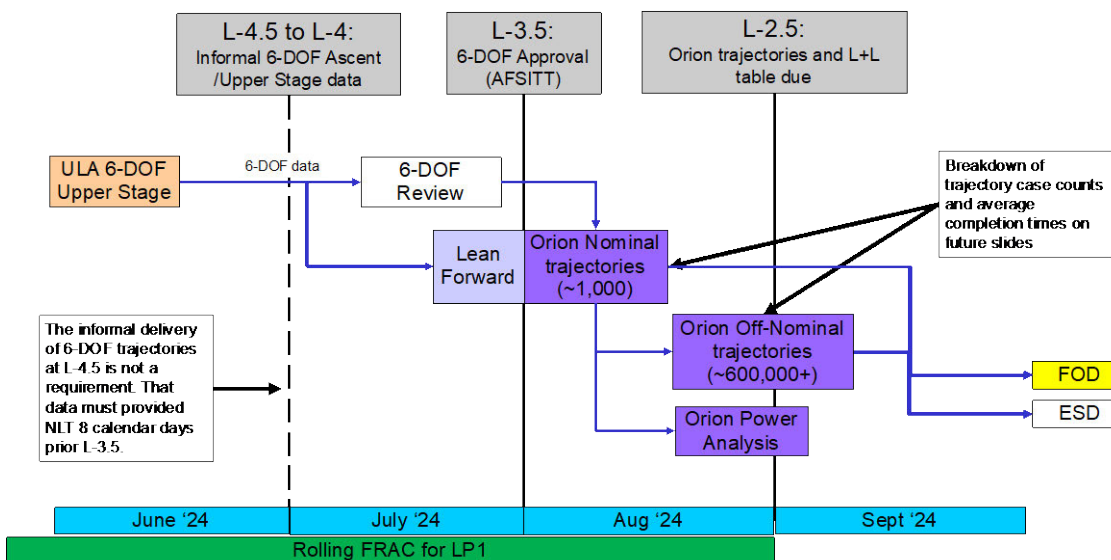
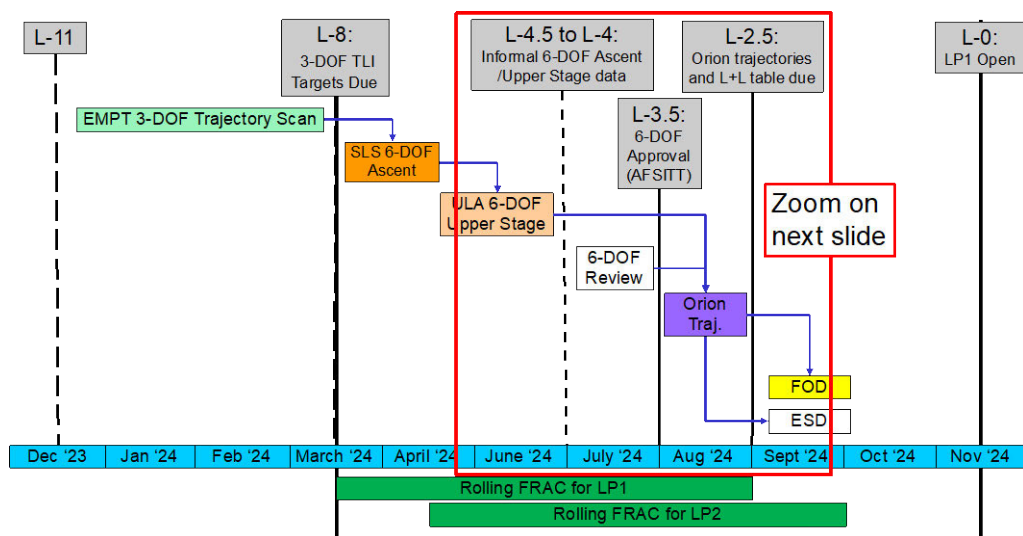
SLS

- 19 IFAs with 13 of those cross program
- 7 Addressed by Special Topics, Hydrogen leaks and Debris
- 5 related to FTS component qual exceedances, 1 to SLS FSW

SE&I will track all Cross Program IFAs

• Mission Analysis & Integrated Assessments (MAIA)

- Orion trajectory design needs to have nominal and off-nominal trajectories completed by L-2.5 months to provide products to FOD and M2M through MAIA forum
 - Current timeline allocates officially one month, and this is not sufficient
 - Leaning forward and starting work early is required, but still not always sufficient
- Recommendation to re-evaluate rolling FRAC schedule to allocate Orion trajectory design more time for final trajectory generation
 - MAIA will take the lead and bring forward recommendation for implementation



- **12 of 12 Artemis I ESD Flight Test Objectives successfully achieved**
- **17 of 18 Refined (Refined means the original 12 were divided amongst Programs) Artemis I ESD Flight Test Objectives were achieved (or expected to be achieved)**
 - 2 FTO assessments are currently in work, expected to be achieved
 - ESD-FTO-20-EM1: Determine entry, descent, and landing, integrated vehicle systems performance and critical events
 - ESD-FTO-29-EM1-InSpace/EDL/Recovery: Characterize Orion integrated systems performance post separation from ICPS until CM/SM separation
 - Action assigned to define closure plan for remaining 2 FTOs
 - 128 Measures of Performance within the 18 Refined ESD FTOs
- **1 of 18 Refined Artemis I ESD Flight Test Objectives was achieved with limited debris data analysis**
 - ESD-FTO-28 - Identify any potential liftoff, ascent or separation debris capable of capture with available imagery
- **Program FTOs have 83% (121) achieved or expected to achieve, 23 partially achieved, 2 not achieved (Parachute and Forward Bay cover recovery)**

- **Vehicle and trajectory flight performance from liftoff through LEO insertion was assessed and compared well with preflight simulation predictions**
- **Orbital Insertion within requirements**
- **Control performance, attitude control margin, and Pogo stability were assessed from liftoff through ICPS-Core Stage separation. Performance and margins were good and compared well with preflight prediction**
- **Liftoff clearance**
 - Liftoff imagery and photogrammetry was obtained and used in liftoff clearance analysis. Clearances were within statistical boundaries used in preflight simulations.
- **Umbilical clearances**
 - OSMU LAS QD maintained positive vehicle clearance
 - Overall behavior of TSMU umbilical is within the range of what was predicted by the analysis model and what was seen during URRT
 - EGS VS , CSFSU, CSITU (Aug 2023), ICPSU (Dec 2023) are still in-work
- **All in-flight separations were determined to be successful with no recontact**
 - LAS pitch-over occurs faster than expected most likely due to plume impingement
- **Disposal - Impact points were well within requirement for minimum distance from land**

- **Artemis I Abort configuration**

- No auto triggers active (except FTS), no ICPS Emergency Detection System, no LAS abort capability
- CS and Orion triggers were in detect only mode
- Mode 2 UAS was only automated abort mode
- AOA, abort during ICPS flight required manual execution

- **Core Stage**

- All assessments show sufficient margin between nominal performance measurements and the Artemis I abort trigger thresholds
- Note that the approach for SLS GN&C abort trigger design for Artemis II and beyond will have additional margin applied where possible to further reduce the chance of a false positive abort
- Boost phase triggers may be similar to Artemis I, but other phases should be much higher

- **No EDS system but team did assess ICPS performance parameters associated with Artemis II abort triggers where possible**

- The Guidance, Navigation, and Control (GN&C) was nominal during ascent. No anomalies were observed in the GN&C performance
- Tank pressures were nominal with the exception of LH2 tank pressures failed to decrease to two commanded pulse venting sequences between CS separation and PRM start
 - Artemis II abort limit set above mechanical relief valve limit
 - LH2 pressures are an auto abort parameter for Artemis II but the Artemis I flight pressures remained below MEOP (and Artemis II auto abort limit)

- **Orion Abort Detection Logic (ADL) performed as expected during flight**

- **Used data from rollout, launch, and ascent flight to confirm the design loads in SLS-RQMT-045-01 Rev E**
- **No flight data exceeded design loads**
 - There are some minimal event level exceedances
 - There are also a small number of areas where reconstruction efforts show poke outs
- **Measured mode frequencies all within 6% of model predictions**
- **Observed damping higher than CLA and GN&C assumptions**
- **JLTT recommends:**
 - No full reconstruction cycle needed
 - Already delivered MAC2a loads will be incorporated into SLS-RQMT-045-01 for Artemis II delta-certification as is
 - Data assessment will continue to determine if any methodology updates are needed for future planned analysis cycles
 - Will bring recommendations to the JICB prior to implementation

- **Aerodynamics**

- Generally good agreement between flight measurements and model predictions with no database or spec updates recommended, except for expected updates to base force and base pressure
- Buffet objectives partially met
 - 45 degraded or lost sensors from ice/frost limiting analysis
 - Comparison of wind tunnel to flight generally favorable, but some exceedances observed (JLTT assessing impacts, no impact expected for Artemis II at this time)

- **Aerothermal**

- All objectives met with no spec changes expected from the flight except the base heat shield
 - TPS cork combustion occurred as expected, models being updated for CS 2/3 (to be discussed by SLS)

- **Interface thermal**

- No model updates necessary

- **Liftoff Environments**
 - Liftoff acoustics generally within spec
 - IOP environment generally within spec
 - Duct overpressure timing slower than expected
- **Ascent aeroacoustics**
 - Generally within spec
 - High frequency exceedances in some portions of the vehicle being investigated
 - No update to spec is required at this time
- **Vibe and Shock**
 - Generally within spec
 - No model updates necessary
- **Venting – no model updates necessary**
- **Debris – Generated 9 IFAs, 6 for SLS and 3 for EGS (Special Topic)**

- **Pre-launch Performance**

- Propellant loading and replenish algorithms controlled within the defined LCC to provide on board masses within the predicted bands.
- Hazardous gas monitoring of the vehicle system volumes showed system leakages well within bounds of the Launch Commit Criteria.
- Umbilical connections in the ICPS and Core Stage hydrogen systems experienced leakage higher than expected but utilized preplanned contingencies and approved waivers to pass Launch Commit Criteria. (Special Topic)

- **Integrated System Validation**

- Operations performed during the tanking tests and propellant loading operations proved the fuel bleed system performance was within analysis results and addressed one of the integrated system performance concerns

- **Optimizing loading timeline for Artemis II**

- **Minor OMRS and LCC updates in work**

- **Integrated Avionics and Software (IAS) - the ground and flight vehicle software and integrated avionics system hardware performed very well**
 - EGS- SCCS & GFAS no countdown or flight following anomalies
 - SLS - performed nominally. One pre-flight anomaly for unexpected loss of comm message, fix implemented in FCAS 15.2.3
 - Orion - Avionics and SW performed well, 5 cross program related IFAs noted
 - 3 SW defects to be fixed, 2 under investigation (cross-program)
- **Electromagnetic Environmental Effects (E3)**
 - 23 lightning events observed. Only one event came close to reaching retest requirements (SLS)

- **The cross program DOLILU system, as outlined in ESD 10029 Vol 3, performed extremely well throughout all Design and Assessment Cycles for Artemis I launch support**
 - On launch day, DOLILU successfully designed SLS boost stage I-Loads (Initialization Loads) based on measured winds/atmosphere and then uploaded the I-Loads to the three SLS Flight Computers
 - The upload also included the pass-through TDD (Time Dependent Data) file selected for the launch day
 - The DOLILU I-loads were verified by running them and the DOL wind in a 6-dof trajectory simulation and comparing output to trajectory and load constraints
- **DOLILU wrote no non-conformances on launch day**
- **All pertinent Artemis I data was saved for archival**
 - An informal summary of DOLILU Artemis I was saved on the DOLIAHT website [here](#)
- **Lessons learned were captured and codified as actions**
- **There are no fundamental changes to the DOLILU system required as a result of Artemis I**

- **Overall Integrated Comm, Network & Tracking (ICAN) performed very well for Artemis I**
 - Supported mission objectives and data for operations and engineering
 - Testament to extensive testing pre-flight
- **Several ICAN anomalies were noted**
 - Data dropouts/backlogs between DTE (KUS/PDL/BDA) and MCC, LCC, and HOSC
 - Noted in testing, adjustments made prior to flight with risk accepted at daily board
 - Minor backlogs reported at JSC and LCC during launch support with no impact to operations
 - Loss of Orion forward link after handover to PDL
 - Forward link reestablished after handover to TDRS
 - Cause was SW bug in DTE SW, will be fixed for Artemis II
 - Loss of Orion return link for 8 minutes, known procedure work around not implemented
 - HW/SW fix and/or procedure update for Artemis II
 - Loss of Goldstone (FOD Special Topic)
 - Useability of the external tracking sites at Santiago (AGO) and Hartebeesthoek (HBK)
 - SSC 3-way doppler sites not able to be used during Artemis I, investigation in progress
 - MCC-DSN connectivity issues
 - Several instances of forward and return link outages due to loss of connectivity between MCC and DSN, minimal impact to operations

- **RF spectrum issues noted**

- Potential AT&T S-band cell phone tower signals interfering with SLS DFI telemetry downlink. Early testing with tower at full power to ensure no issue (closed)
- RF interference/multipath
 - Multipath concern with multiple RF signals – ground stations mods done and tested (closed)
 - Multipath issues with DFI antennas radiating into the ML, minor loss of data (Closed)
- Spectrum conflict during Space-X launch and Artemis L-1 day FR pre-launch operations (Closed)
- Signal strength fluctuations at PDL, appears caused by RF signal issue external to PDL
- Momentary drop in return link telemetry was noted when using DSN Goldstone during normal business operation hours (M-F 0800-1700 PT) due to military S-band RF interference

- **ICAN Process Findings**

- Late pre-mission Orion RF analysis
 - Updated ICAN charter to include RF ICDs/analysis, updating CNTAD to reflect roles and responsibilities, bringing launch period specific analysis to JICB (Aug '23)
- SLS data loss at MSFC/HOSC
 - Due to MCC KSC Serial Conversion Processor (SCP) forwarding inadvertently dropped, investigating changing design to make HOSC data flow independent from JSC (Dec '23)
- Bermuda (BDA) antenna hit cable wrap limit
 - Limit reached causing off pointing and loss of non-mandatory BDA OFI and DFI telemetry for 27 sec - operator error, SCan implementing pop-up warning for condition (Aug '23)
- Loss of Downlink data due to misconfigurations at DSN
 - Proximate cause was human/procedural error in communication between MCC and DSN, configuration table will be implemented for Artemis II

- **All actions and forward work were noted as either closed or with ECDs**

- **Range Safety**

- Core Stage disposal model comparison agrees favorably and supports methodology for future flights
- Flight Safety System performance met in-flight predictions
- FTS component in-flight environmental qual exceedances, coordinating with SLD 45 Range safety and on track for closure for Artemis II (SLS-IFA)

- **Reportable Events**

- 385 closed, 5 open (Orion)
 - Artemis I-M008 Debris Noted at OSMU Release
 - Artemis I-M014 In-Flight Burn Debris (USS-1, OTC-2, OM-3)
 - Artemis I-M039 Debris noted prior to PRM
 - Artemis I-M041 Debris noted prior to TLI
 - Artemis I-M043 Debris Noted During FD1 SAW Modal Survey
- Most (252) were associated with debris/ice, 68 were flight hardware concern
- All 385 closed have been coordinated with appropriate technical discipline

- **Mission Objective Validations Partial and Unsuccessful**

- Multiple preflight and launch mostly due to dark conditions (Partial)
- Orion imagery prior to reentry, 2 – Wi-Gig antenna failure (unsuccessful)

- **Issues**

- Prelaunch anomalies (EGS Special Topic – Imagery Tiger Team)
- IOP/SS Water obscured – in work by EGS/SLS
- No public broadcast of Live Orion and SLS downlink during ascent – corrective action in work, MIR action for Artemis II
- Loss of high-quality imagery of CS/ICPS sep due to antenna cable anomaly (BDA) Being corrected for Artemis II. Low qual image was successfully downlinked
- Wi-Gig failure corrected for Artemis II
- No livestream of high-altitude airborne imagery during EDL due to weather alternate landing site

- **All lessons learned and forward work documented**



SE&I Artemis I Lessons Learned



Lesson Learned	Recommendation	Status
Comm Coverage Analysis Roles and Responsibilities - Late notification of 2 min gap in ascent comm coverage for Orion	Update task team charters and roles and responsibilities to capture RF analysis.	ESD 10025 CNTAD updated to document roles and responsibilities. CoFR plan and statements of readiness to be updated to clarify responsibilities for all pre-launch communications link margin analysis. Summary of launch period unique analysis to be brought to JICB (implemented for LP27 and LP28)
Alpha Total (SLI.01), Orion Qbar rule Limits were overly restrictive and could have led to a waiver for Artemis I	Task is to work with Orion to expand the limit for the DOLILU tools	In work by DOLILU team and SLS and Orion. Action (CPIT-AI-580 ECD 9/25/23, Orion Qbar) is being worked. Updated rules will be documented in an update to DOLILU QA rules, SLS-RPT-262-02 (Early '24)
Orion off Nominal Analysis originally didn't have sufficient time in-rolling analysis cycles for off-nominal analysis	Orion trajectory design needs to have nominal and off-nominal trajectories completed by L-2.5 to provide products to FOD and M2M through MAIA forum	CPIT AI-577 MAIA will take the lead and bring forward recommendation for implementation. ECD 8/14/23



SE&I Artemis I Lessons Learned



Lesson Learned	Recommendation	Status
Pad access - Assess means of pad access for FTS ETE testing and other potential areas that would enhance launch availability	Enable ETE FTS testing on pad vs. rollback or waiver approval	CESD action to address Pad access SLS/EGS team assessing fixed and portable options to enable pad access
LH2 leakage during Artemis I launch campaign. Leaks in TSMU QD, TSMU poppet postlaunch and ICPS boot	Work to mitigate/eliminate leaks causing LCC violations	EGS working with SLS on potential QD improvements on future missions. Significant work has been done to evaluate the TSMU can configuration and make additional improvements from those implemented during the Artemis I campaign. ETC: 10/13/23 EGS worked with SLS/SPIE on seal design modification and qualification
Develop augmentation to communication assets to improve data throughput and minimize impacts to science	Long term investments required – through combination of government assets and commercial services. Lunar-capable ground terminals and lunar relays necessary to reduce DSN burden	Investments tied to Artemis I lessons were included in SCan PPBE25 and are subject to Agency decision including: LCS Upgrades, DSN upgrades, and network surge staff increases

Lesson Learned	Recommendation	Status
CoFR Lessons Learned - Launch period analysis - ISMC - CoFR documentation	- Review launch period specific analysis at CESD hosted JICB - More technical depth at ISMC and less reliance on scorecards. Add another ISMC dry run if launch slips occur - Update CoFR documentation to reflect as executed and incorporate learning from execution	- Closed, R&Rs updated, analysis tracking in progress - ISMC approach update targeted for 12/23. - CoFR documentation update to reflect as executed and incorporate learning is being addressed with ESD 10020 Rev H to JICB 7/26, M2M CB 8/3.
Integrated System DCR	- Institute an Integrated system DCR before the first crewed flight	- ESD requirements have been updated with verification requirements to provide a more complete integrated system set (ECD 7/23) - Work on Integrated System DCR plan Oct '23
Integrated drawings	- Enhance integrated drawing process to ensure needs are met for IPCA - Add ITCO test drawings where needed	- CPIT-AI-550 Create Artemis II 97M drawing series - Drawings submitted to IMS - CPIT-AI-551 Create ITCO drawings in support of assembly process
Imagery Requirements for crewed flight – pre plan PAO/OCOMM and science imagery needs	Develop imagery (including PAO/OCOMM) and science needs for crewed Artemis II mission and then develop executable plan to meet them	- Artemis Imagery Working Group has taken on the task to develop the ACD PAO/OCOMM imagery plan. ECD 12/23 - The MDB, ESD 10026-EM2, is going to be updated with science imagery needs

- **SE&I recorded several actions during ESI PFAR, 7 formal and 11 informal**
 - Formal actions will be closed at an SE&I forum (e.g., JICB)
 - Most informal actions have already been closed
- **Open work that requires product updates/modifications are tracked as part of Artemis II performance to plan**
- **Lessons learned closures will be addressed with Artemis I Lessons Learned Closure Plan presentation**
- **All IFAs will be tracked by SE&I based on burn down inputs provided by the Programs after Artemis I PFAR**

ESI PFAR Success Criteria	Completed	Comments
SC #1: ESI post flight assessment activities needed to provide the information and data to support the preparation of the CESD Integrated Post Mission Report (as defined in ESD 10018), including documenting results of post-flight analyses and assessments, integrated system performance, integrated system validation, and integrated model validation and accomplishment of mission objectives and Flight Test Objectives (FTOs), have been completed.	Green	Note: Two FTOs pending
SC #2 All Cross Program nonconformances, waivers, deviations, anomalies, and facility-related problems have been adequately documented and dispositioned. Any that are still open have a closure plan.	Green	
SC #3 The impact of Cross Program nonconformances, waivers, deviations, anomalies, and facility-related problems on future missions has been assessed and documented.	Yellow	Note: Includes IFAs
SC #4 ESI Reports and other documentation have been retained for performance comparison and trending.	Green	Note: Informal Action: Have all ITTs confirmed repository/documentation numbers (ref. Task Agreements). (Post-flight report may include.)
SC #5 Radio Frequency (RF) Spectrum Interference Issues Identified	Blue	
SC #6 Recommendations for updates to the system design, test and operations procedures, or safety inspections have been identified and a credible plan exists to incorporate the changes.	Yellow	Note: Heatshield, Cont. pad access, parachute recovery



Backup



B	Blue: Complete; no issues or open work remain
G	Green: On track / schedule supports completion of open work and closure of minor technical issues
Y	Yellow: Open work and/or technical issues have the potential to pose a threat to readiness for Artemis II
R	Red: Open work and/or technical issues currently cannot be closed with current plans and are a threat to readiness for Artemis II; impact if not resolved

Action #	Action (short/specific description)	Assignee	Team	Board (Action Tracking/ Closure)	Due Date	Status
Formal CPIT-AI-576 (AI-ESIPFAR-001)	Put together consolidated radiation monitoring story Special Topic for the Artemis I PFAR. Provide what is known thus far and fwd plan to pull it together for a future briefing for unknown data at the time of PFAR. Include Artemis II plans.	Susan Baggerman	HH&P	CPIT	07/19/23	Closure Submitted
Formal CPIT-AI-577 (AI-ESIPFAR-002)	Bring forward options on improving trajectory design analysis strategy (nominal and off-nominal trajectories). (Work with stakeholders, including VM, FOD, EMPT, SA&I FAL, CESD CE, etc.).	Roland Martinez	MAIA	CPIT/JICB	08/14/23	
Formal CPIT-AI-578 (AI-ESIPFAR-006)	FTWG to readdress ESD-FTO-28-EM1 recommendation and provide clarification (Achieved w/caveat or Partially Achieved).	Wyatt Fisher	FTWG	CPIT	07/19/23	Closure Submitted
Formal CPIT-AI-579 (AI-ESIPFAR-007)	FTWG to review overall process and categories for characterizing FTOs.	Wyatt Fisher	FTWG	CPIT	09/25/23	
Formal CPIT-AI-580 (AI-ESIPFAR-011)	Revisit Orion Qbar constraint to determine if there is need to come up with alternate true load indicator/ expand limits. (ref. DOLILU LL).	Jim Geffre	Orion	CPIT	09/25/23	
Formal CPIT-AI-581 (AI-ESIPFAR-014)	Report on any other imagery assets that should be considered for addition to Artemis II.	Joe Voor	JETI	CPIT	09/25/23	
Formal CPIT-AI-582 (AI-ESIPFAR-018)	Streamline reporting at MMT among reporting teams (CITM and MRM - examples). (Note: Due before 1 st MMT Sim in Sept.)	Wayne Jermstad, Lori Childress, Sarafin/Ramsey	SE&I, SMA, MM	CPIT	09/18/23	

Action #	Action (short/specific description)	Assignee	Team	Board (Action Tracking/ Closure)	Due Date	Status
Informal AI-ESIPFAR-003	Provide ECDs for achieving FTOs 20 and 29.	Tom Ellis	FTWG	OSB - incl in charts	07/19/23	Closure Submitted
Informal AI-ESIPFAR-004	Provide closure plan for expected to be achieved FTOs.	Tom Ellis, Rob Rowland, and Wyatt Fisher	FTWG	OSB - incl in charts	07/19/23	Closure Submitted
Informal AI-ESIPFAR-005	Improve Data Exchanges (Data Access Roadmap) - covered in LL.	Wyatt Fisher	FTWG/DIITT	OSB	08/14/23	
Informal AI-ESIPFAR-008	Provide ECD for TSMU Clearance Performance Analysis (will need to track as open work if further out ECD).	Dr. Robin Pinson	AFSITT	OSB - incl in charts	07/19/23	Closure Submitted
Informal AI-ESIPFAR-009	Integrated aborts - new date for IFA Closure (p. 16).	Jacob Madalon	MSAIT	OSB - incl in charts	07/19/23	Closure Submitted
Informal AI-ESIPFAR-010	Provide insight on LAS jettison motor plume impingement.	Jim Geffre	Orion	CPIT	Complete	Complete
Informal AI-ESIPFAR-012	Forward discussion on including vehicle induced environments to ML as part of JICB/CP area.	Wayne Jermstad, Anton Kiriwas	SE&I, EGS	OSB	3-4 mo	
Informal AI-ESIPFAR-013	Include in FOD PFAR charts plan to obtain insight into network risk posture for CoFR.	Rick Labrode	FOD	OSB - incl in charts	07/19/23	Closure Submitted
Informal AI-ESIPFAR-015	Discuss PRD closed loop tracking prior to PFAR.	Wayne Jermstad, David Beaman, Anton Kiriwas	SE&I	OSB - incl in charts	07/19/23	
Informal AI-ESIPFAR-016	Coordinate among SE&I, Programs, and IRWG on how risks are communicated at the PFAR. Incl. review of agenda/content layout for updates (SE&I/full List summary with new items/details in follow-on IRWG topic).	Orion, SLS, EGS, SE&I, IRWG	All	OSB - incl in charts	07/19/23	
Informal AI-ESIPFAR-017	Update IRWG charts (p. 7) to clarify Range Safety "requirement" (not tailoring).	Dan Mulligan	IRWG	OSB - incl in charts	Complete	Complete
Informal AI-ESIPFAR-019	Provide listing of repository/documentation numbers (ref. Task Agreements) to FTWG/Flt Test Report. (Ref. SC #4) - quick turnaround (to support PFAR).	FALS	CSI	OSB	07/10/23	Closure Submitted
Informal AI-ESIPFAR-020	Provide Hazard Report/Post-Flight Report expectations to FTWG.	Edgar Rivera	SMA	OSB	Complete	Complete

- **New or updated Cross Program Risks**

- 12172 SLS Potential Debris Damage
- 14125 IOPSS Water in Booster Nozzle
- 13626 Integrated Operations for Artemis II
- 13627 Integrated Operations for Artemis III
- 14427 High Speed Imagery Lighting for Launch
- 14537 Artemis II Launch Team Certified Personnel for Firing Room LCD Ops
- 13544 Enterprise Schedule Threats to Artemis II
- 14397 Enterprise Schedule Threats to CESD Readiness for Artemis III

- **Potential Risks**

- MAIA trajectory product timeline LL
- FTWG DRI NC/waiver LL
- Environments VAB Access Recommendation
- ICAN Ground Site, test residual assessments
- Imagery tracking Spares, dark launch
- From Tiger Team activities (e.g. Pad access, ML damage, imagery, cryo)
- Potential new risks will be worked through the IRWG

- **Details will be discussed by the IRWG**

-
- **A01-IFA-001**
 - 1L3#27 GSE-ECS-007 ECS ICPS/AFT Purge System Anomaly
 - **A01-IFA-004**
 - Artemis I Post Launch Debris Seen In Imagery (Joint Environments Task Team (JETT))
 - **A01-IFA-005**
 - Artemis I Post Launch ML/Pad Damage (JETT)
 - **A01-IFA-011**
 - Post Launch FOD Items from ML/Pad Walkdowns (JETT)
 - **A01-IFA-034**
 - 1L1#19 GSE-ECS-006/GSE-ECS-007 Temporary ICPS/FWD and ICPS/AFT Purge Pressure Excursions

-
- **A01-IFA-006**
 - Incorrect Exposure Settings on 32 of 33 high speed film cameras (JETI)
 - **A01-IFA-009**
 - High H2 Concentrations in LH2 TSMU Post Launch (Propulsion Integration Task Team)
 - **A01-IFA-007**
 - High speed digital 30-P1 camera stopped functioning pre-launch (JETI)
 - **A01-IFA-008**
 - High speed digital 30-P3 camera had interlacing/ghosting and incorrect timing (JETI)

- **A01-IFA-029**
 - Extended Loss of Orion Data During Change from Uncoded to Coded Telemetry (ICAN)
- **A01-IFA-033**
 - Loss of Goldstone Support GMT 338 (ICAN)
- **A01-IFA-040**
 - ICMP Ping Intermittent Drop Outs (ICAN)
- **A01-IFA-041**
 - Loss of Orion Forward Link Following Handover to PDL (ICAN)
- **A01-IFA-042**
 - TDRS 275 Unable to Lock to Orion DG1M3 Coherent Telemetry (ICAN)

- **A01-IFA-036**
 - SM/OSA SAJ fairing hinge plate delamination (Joint Environments Task Team)
- **A01-IFA-012**
 - SM Propulsion pressure regulation unit anomaly (JETT)
- **A01-IFA-014**
 - SAJ Panel #1 missing RTV and possible loose RTV (JETT)
- **A01-IFA-013**
 - SM Helium latch valve position driver anomaly
- **A01-IFA-066**
 - NAV Channel 1 Unexpected Velocity Step Function

- **A01-IFA-051**
 - CAR Software Sending IG Rate Commands After Brake Engage Command
- **A01-IFA-015**
 - SM Prop Helium Valve Position Indicator Issues
- **A01-IFA-096**
 - C2b Battery Temperature Sensor Out of Family
- **A01-IFA-102**
 - SM PDE1B in Standby Mode after PCDU1B event (undetected by Prop FDIR)
- **A01-IFA-105**
 - Aux Leak Detection
- **A01-IFA-110**
 - SM RCS Thruster Pulsing

- **A01-IFA-016**
 - Unexpected Cryogenic Level Sensor System (CLSS) Loss of Comm Caution (Propulsion)
- **A01-IFA-021**
 - Flight Termination System (FTS) Shelf 1A Vibration (Range Safety)
- **A01-IFA-022**
 - Flight Termination System (FTS) Shelf 1B Vibration (Range Safety)
- **A01-IFA-023**
 - Flight Termination System (FTS) Shelf 4 Vibration (Range Safety)
- **A01-IFA-024**
 - Intertank Skin Vibration (Range Safety)
- **A01-IFA-025**
 - FTS System Tunnel Vibration (Range Safety)

- **A01-IFA-019**
 - Unexpected Debris Liberated from Booster Throat Plug (Integrated Hazards, Debris Induced Environment)
- **A01-IFA-068**
 - 1L1#66 CS-HazGas-004 CS LH2 Umbilical Carrier Plate Cavity Concentration Anomaly (Integrated Hazards)
- **A01-IFA-073**
 - Debris: Core Stage Engine Blanket Outer Layer (Integrated Hazards, Debris Induced Environment)
- **A01-IFA-074**
 - Debris: CS LH2/IT Flange Closeout TPS (Integrated Hazards, Debris Induced Environment)
- **A01-IFA-075**
 - Debris: CS Pressurization Line Bracket Closeout TPS (Integrated Hazards, Debris Induced Environment)
- **A01-IFA-076**
 - Debris: CS Feedline Bracket Closeout TPS (Integrated Hazards, Debris Induced Environment)
- **A01-IFA-119**
 - Debris: CS Sensor Island Closeout TPS (Integrated Hazards, Debris Induced Environment)



ARTEMIS

Artemis I PFAR

M2M Safety and Mission Assurance

July 19-20, 2023

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Lori Childress
Acting M2M SMA Director

SMA PFAR Support



- SMA cross-program (CP) Integration Task Teams (ITTs) or Working Groups reviewed the Integrated IFAs for impact:
 - Integrated Hazard Analysis (IHA) ITT
 - Quality Assurance ITT (QuITT)
 - Cross-Program Probabilistic Risk Assessment (XPRA) ITT
 - Failure Modes and Effects Analysis (FMEA) ITT
 - Crew Survivability ITT
 - Integrated Risk Working Group (IRWG)
- Collected lessons learned from the M2M SMA team, including ITT/WGs and launch and mission support team



SMA PFAR Summary



- IHA ITT identified 9 debris and 4 comms related IFAs with potential impacts to the CPIHA
 - Forward work item added to the corresponding cross-program hazard report to assess the closure of each IFA/PRACA item for possible impacts to current control strategy.
 - CPIHA HR# ESI-549-A2: In-Flight Impact to the Integrated Vehicle, documented in ESD 10121-ANX05 ESI System Safety Analysis Report Cross Program Integrated Hazards for Artemis II and Artemis III: Loads, Environments, and Flight Control
 - 9 Debris IFAs: A01-IFA-019, A01-IFA-013, A01-IFA-036, A01-IFA-004, A01-IFA-011, A01-IFA-073, A01-IFA-074, A01-IFA-075, A01-IFA-076
 - CPIHA HR# ESI-268-A2: Loss Of Communications during Operations, documented in ESD 10121-ANX02 ESI System Safety Analysis Report Cross Program Integrated Hazards for Artemis II and Artemis III: Radiation, Electromagnetic Effects and Loss of Communications
 - 4 Communication IFAs: A01-IFA-033, A01-IFA-040, A01-IFA-041, A01-IFA-042
- IRWG risk findings will be discussed by Dan Mulligan (IRWG Lead) in tomorrow's special topic



Post-Flight Documentation & Open Work



- ESD 20062 ESD Planetary Protection Post-Launch and End-of-Mission Report has been submitted for signature
- Forward work items added in the appropriate IHA HRs to evaluate the closure rationale on the debris and communication IFAs identified by the IHA ITT



SMA Lessons Learned Activities



- 42 Lessons Learned (LL) documented by M2M SMA Team
- 7 LLs being elevated for awareness at the Artemis PFAR
 - Mission/Console Support LL
 - SMA Mission Risk Matrix (MRM) Updates
 - Lack of R/T Operational Hazard Control Process
 - Flight Preparation LL
 - Hazard Modification post PRE-FRR-45d
 - QuITT CoFR Score Card update
 - Quality Processes LL
 - GMIP Reduction and process realignment
 - CP-NC backlog
 - CP-Corrective Action Communication

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Backup



SMA Mission/Console Support LL



Title	Description	POC	ECD	Status	End State
SMA Mission Risk Matrix (MRM) Updates	Investigate updates to MRM format to improve communication	Phillip Sterbenz	Need to have in place by joint integrated SIMs (L-6mo)	Considering possible format changes	Reformatted MRM that better communicates the same information
Lack of R/T Operational Hazard Control Process	Work with Program SMA and FOD Safety to develop an Operational Interface Procedure (OIP) to document a process to change, update, or add operational hazard controls after the OCAD database has been locked down for the mission.	Tieva De Koninck	Spring 2024	New OIP in work	New OIP will be submitted for approval at Artemis II Flight Operations Review (FOR)

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SMA Flight Preparation LL



Title	Description	POC	ECD	Status	End State
Hazard Modification post PRE-FRR-45d	Safety Issue Briefing to the appropriate boards in-lieu of immediate CPIHA cause update.	Edgar Rivera	Summer 2023	Change being incorporated into ESD 10010 Rev G update.	Updated ESD 10010 with safety issue briefing process in place.
			Spring 2024	New process being documented to attach safety briefings to HR cause in HR tool until incorporated.	
QUITT CoFR Score Card update	QUITT initially duplicated effort for Acceptance Data Package Review and Integrated Physical Configuration Audits. CP CM was also doing the same	Shak Ferdousi from QUITT	July 2023	Updating the QUITT Task Agreement to de-scope those from QUITT's purview.	QUITT will not be reviewing the Program reviewed ADP info as that is being tracked by CP Configuration Management

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SMA Quality Processes LL



Title	Description	POC	ECD	Status	End State
GMIP Reduction and process realignment	EGS GMIP development and implementation needs to be at the EGS Program Level (versus the CP level). EGS SMA opportunity to implement Risk Based Assessments (RBAs) from Artemis I WADs to reduce GMIPs.	Shak Ferdousi from QuITT and EGS S&MA Quality	June 2023 for GSDO-PLN-1232 rev E. EGS Docs still TBD	GSDO-PLN-1232 documents the CP policy for the ongoing activities captured in GSDO-PLN-1231 and GSDO-RPT-1332	Update GSDO-PLN-1231, create GSDO-RPT-1332 as a DM documents while keeping GSDO-PLN-1232 as a CM managed CP doc
CP-Nonconformance (NC) backlog	A large amount of backlogged CP NCs drove to have special process called “war room” by EGS	Shak Ferdousi from QuITT and EGS S&MA Quality	10/1/23	EGS SMA and Program are tracking similar action	Tracking EGS LL

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SMA Quality Processes LL



Title	Description	POC	ECD	Status	End State
CP-Corrective Action (CA) Communication	Not all Programs are using CP-PRACA to share CP CA among Programs	Shak Ferdousi from QuITT	TBD	CP Community will provide their approach for handling CP CA. Initial agreement with Programs is being captured in ESD 10010 draft to use CP-PRACA for tracking and communication of CAs but more details are needed to understand how each Program will ensure CA initiation and closure will occur between the CP-PRACA tool and the effected Programs/Providers.	QuITT will bring CP CA communication story to CPIT and work to find an integrated approach for communicating CA between Programs.

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List of Artemis I SMA Lessons Learned



ID	Title	ID	Title
SMA-LL-A1-01	Hazard Modification post PRE-FRR-45d	SMA-LL-A1-13	Lack of pre-flight approved/coordinated R/T DFTO process
SMA-LL-A1-02	Lack of R/T Operational Hazard Control Process	SMA-LL-A1-14	Some MER handovers fell on top of major mission activities and/or FOD handovers that forced the delay of handover and increased shift durations.
SMA-LL-A1-03	CP-NC backlog	SMA-LL-A1-15	Lack of Pre-Flight training focused on MER Processes
SMA-LL-A1-04	GMIP Reduction and process realignment	SMA-LL-A1-16	FOD Sims are designed to stress the edges of the operating envelope and can result in negative training and skew expectations for actual mission execution.
SMA-LL-A1-05	QUITT CoFR Score Card update	SMA-LL-A1-17	It is unclear if all changes to the approved residual risk baseline need to be elevated to, acknowledged, and approved at the MMT or only those risks that rise to 3X5 or higher.
SMA-LL-A1-06	SMA Mission Risk Matrix (MRM) Updates	SMA-LL-A1-18	Don't change the FSOARD process in the middle of the mission (i.e., don't delete items from the flight binder). Need a plan for recurrences vs new anomalies
SMA-LL-A1-07	CP-Corrective Action Communication	SMA-LL-A1-19	Contacting console operator-VSE within 12 hours of a console shift should be avoided
SMA-LL-A1-08	SMA Team Coordination	SMA-LL-A1-20	Need a full console, handovers challenging with only half console/one DVICE.
SMA-LL-A1-09	Exercise MER Processes in FOD simulations	SMA-LL-A1-21	Access to NASA Imagery Reporting Database (NIRD)
SMA-LL-A1-10	Timing of elevation of anomalies to Common Issue Tracking Matrix and Mission risk Matrix	SMA-LL-A1-22	Could use more training in the proper flow of Chits, ARs and Flight Notes. Could use more sims using chits/ARs/FNs.
SMA-LL-A1-11	ART meeting coordination/execution not consistent between ARTs.	SMA-LL-A1-23	SME review requests sent from the console should be FYI instead of response required if the console plans on signing the product without waiting for input.
SMA-LL-A1-12	Team collaboration – multiple ways of disseminating MER info (email, TEAMS, internal notes, etc.) that limit access to info	SMA-LL-A1-24	Try to write shift summary as early as possible (should be done before handover).

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List of Artemis I SMA Lessons Learned (cont)



ID	Title	ID	Title
SMA-LL-A1-25	Console should initiate an FSOARD entry for every CITM item but may have additional.	SMA-LL-A1-34	Document CONOPS/Enterprise-level scope and capability expectations to guide LoM analysis and crew survival options (e.g. rescue capability)
SMA-LL-A1-26	Console scheduling – certain shift transitions should be avoided to avoid oversubscribing console operators	SMA-LL-A1-35	Pre-declaration of Test Flight Damage
SMA-LL-A1-27	Train more people earlier for console support due to potential for attrition and long training lead time	SMA-LL-A1-36	Designation of Artemis I Mission Objectives in the MDB
SMA-LL-A1-28	Addition of sims because Artemis I launch slips was beneficial for team readiness	SMA-LL-A1-37	GIDEP/NASA Advisory Elevation
SMA-LL-A1-29	Successful Backroom Mission Operations (Internal)	SMA-LL-A1-38	Lessons Learned Tool
SMA-LL-A1-30	SMA Backroom (Conference Room 204/ Bldg. 20) Computer System Failure (Internal)	SMA-LL-A1-39	XPRA Model Updates Post Flight
SMA-LL-A1-31	Staffing of Backroom Team (Internal)	SMA-LL-A1-40	Candidate risk approval timeliness
SMA-LL-A1-32	Improve process for capturing board decisions which direct documentation changes	SMA-LL-A1-41	Cross-Program Risk Review agenda setting
SMA-LL-A1-33	Increase access to multi-mission schedule milestones	SMA-LL-A1-42	Milestone review CP risk data





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Artemis I PFAR

Programmatic & Strategic Integration

July 19-20, 2023

M2M PP&C
Maritza Alexander

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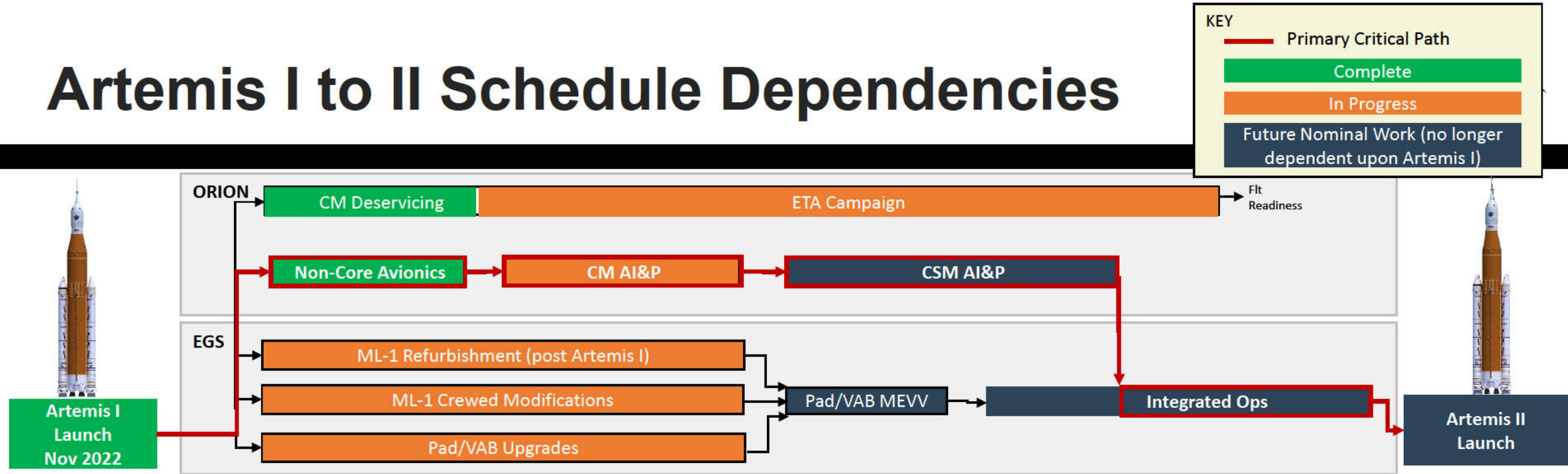
Agenda



- Artemis I to II Schedule Interdependencies and Lessons Learned
- Post Artemis I Enterprise Cost Threats
- Configuration Management Artemis I Open Change Requests



Artemis I to II Schedule Dependencies



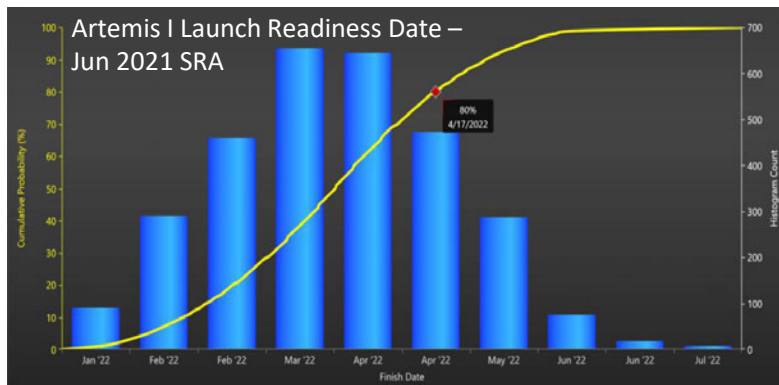
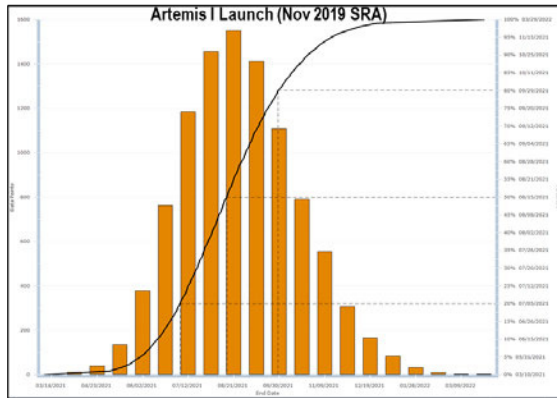
- **Artemis I launch delays directly impacted Artemis II activities dependent on the launch**
 - Orion's use of Artemis I hardware for Artemis II CM and ETA
 - EGS's ability to complete the necessary Artemis II modifications, refurbishments, and upgrades until ground systems/facilities were available
- **With the delays experienced on the Artemis I launch, Orion's re-use of specific Artemis I non-core avionics (now complete) became Artemis II's critical path and delayed Orion CSM-2 readiness**
 - Artemis I delays increased pressure and reduced schedule flexibility along these dependent paths

The Artemis I to II schedule dependencies are well understood. Dependent Artemis II activities are either complete or have begun; nominal work remains to get to launch

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Artemis I Enterprise Schedule Assessment Performance



- In early 2020, a detailed Joint Confidence Level (cost and schedule) risk assessment for the Artemis I launch was completed in support of the SLS/EGS rebaseline activity
 - Established a revised Agency Baseline Commitment (ABC) launch readiness date of **Nov 2021** (at a Joint P(70) confidence level); note that this assessment did not include COVID-19 impacts
- In June 2021, the final risk-informed status update for Artemis I was completed for the Operational Readiness Review and presented at a special topic APMC
 - At this point, the Core Stage (critical path driver) had recently been delivered to KSC (Apr 2021) so the assessment results were primarily driven by EGS's Integrated Operations risks
 - P(80) results predicted an **Apr 2022** launch
- Artemis I launched in **Nov 2022**, a year past the ABC date and 7 months past the final status update. Largest drivers for these variances include:
 - COVID-19 impacts (unknown-unknown)
 - Delayed delivery of Core Stage and work traveled to KSC (under-predicted risk)
 - First Time Operations, Technical Challenges; e.g., four WDRs (under-predicted risk)*
 - Weather, including multiple hurricanes (under-predicted risk)

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**EGS's Lessons Learned process provides a full, detailed assessment of operational performance*



Integrated Schedule Considerations

- **Artemis I schedule execution provides critical information for future mission planning; actual performance data and Lessons Learned provide a basis to refine future mission schedule baselines**
 - Improvements identified in production, integration and test flows are being implemented into future planning where possible
 - Along with technical and cost considerations, Artemis I schedule performance has also been factored into the current PPBE process to aid in the refinement of the enterprise manifest
- **Artemis I performance data and Lessons Learned also provide important insights into risk postures and potential mitigations, which will be leveraged in future integrated schedule risk assessments**

Schedule impacts identified from program PFARs (e.g., refined operations flows, updated schedule and technical risks, etc.) will be incorporated into Artemis II enterprise-level schedule risk assessment in the fall timeframe

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Schedule Risk Assessment Lessons Learned



Methodology	Artemis I Approach	Planned Artemis II+ Approach
SRA Type and Schedule Backbone	Integrated assessment using Enterprise-level schedule focused on critical and near-critical path items	No change; approach provided effective analysis tool
Program Collaboration	Enterprise-level assessment that integrated EGS, SLS, and Orion program-provided SRA inputs	For Artemis III+, integrate SRA inputs from all six programs to provide a comprehensive probabilistic assessment for each mission
Uncertainty/Risk Inputs	Programs provided recommended risks and uncertainties using various approaches (performance, SME, discrete risks, historic data, etc.)	No change; team has found that use of detailed performance data is a good indicator of future actuals
Review Process	Once SRA model was completed, results were reviewed with program schedulers, PP&C, program managers, and division leadership	Goal of streamlining future review processes by leveraging existing program channels prior to M2M leadership review
Frequency	As needed; retired enterprise-level SRA after operations moved to KSC (managed by EGS)	Once integrated schedule is mature, conduct assessments as required to support major reviews or to evaluate emerging schedule concerns, balancing concurrent mission assessments

Generally, the Enterprise Schedule Risk Assessment process worked well; future uncertainties and risk modeling will benefit from Artemis I lessons learned

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Path to the Fall Artemis II SRA



	Apr	May	Jun	Jul	Aug	Sep
EGS	Identify schedule impacts for increased shifting assumptions during ML1 Refurb and MEVV	Reflow Artemis II processing and integrated ops schedule to include Artemis I lessons learned and any opportunities		EGS program develops Final Artemis II SRA inputs based on outcomes of Apr-Jun actions	Fall Artemis II SRA inputs are in work by programs; enterprise-level SRA integration will take place in August to support a September outbrief	
Orion	- Create detailed schedule for ML1 Refurbishment efforts - Update EGS Program Risks accordingly		6/15: Orion PFAR	Orion program develops Final Artemis II SRA inputs using recent performance and latest technical data		
SLS			6/12: SLS PFAR	SLS program develops Final Artemis II SRA inputs using recent performance and latest Core Stage 2 traveled work plan		
M2M			6/6-8: Mission Integration Review	6/28: ESI PFAR	M2M integrates program inputs for Final Artemis II SRA	NET for Artemis II SRA outbriefs at M2M, ESDMD, and Agency level as needed

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Summary of Enterprise Cost Impacts

All cost threats and liens resulting from Artemis I results will be managed using existing program threats and liens management process.

Orion:

- Resolving findings from Artemis I lessons learned including additional post flight heatshield analysis and Arc Jet testing and as necessary any potential, software, hardware, or mission profile changes resulting from the tests and analysis work.
 - Program has included budget liens for Artemis II heatshield imagery (SCIFLI) and some initial post-Artemis I heatshield analysis in PPBE25 estimates (~\$6M). Any additional heatshield analysis, testing, or design work is a budget risk to the Orion Program.

SLS:

- Nineteen (19) In-flight anomalies (IFAs) declared (11 cross program and with the Range); Cost threats exist pending disposition of closure plans
 - Action plans and coordination are in place to address prior to the Artemis II mission
 - Funding resolution will be managed by SLS Element Managers as part of their cost threats/liens management processes

EGS:

- Post Artemis I ML-1 Refurb/Mods driving budget and schedule impacts that are being actively managed
 - Estimates continue to be refined, Program protecting \$25M of funding to cover current cost estimates between FY23 and FY24
 - Pneumatic tubing requirements are largest cost driver to-date
 - 25% of systems still require functional checkout – additional cost threat \$TBD
 - Refurbishment driving construction contract extensions and V&V content shift to FY24

EGS Artemis I Open Change Requests Report: Combined Configuration Management Report and Performance to Plan Report (Wiki)



Items highlighted in blue are ready for Board Presentation

Product Number	Product Mission Effectivity	Product Title	Product Board	CR Number	Description of Change	CR Mission Effectivity	CR Approval Board	Lifecycle	Lifecycle Date	Functional Area	ITT
GSDO-PLN-1165	Artemis I	Cross-Program Pad Program Specific Engineering Test - Test Plan	JICB	GSDO-C1013-X	Update to address current errata	NFS	JICB	Coordination	8/25/2023	Systems Integration	
GSDO-PLN-1161	NFS	Cross-Program Vehicle Assembly Building Program Specific Engineering Test - Test Plan	JICB	GSDO-C1129-X	Incorporate errata and retire document	NFS	JICB	Coordination	8/1/2023	Systems Integration	
GSDO-PLN-1129-ANX-02	Artemis I, Artemis II, Artemis III, Artemis IV	Cross-Program Integrated Launch Operations Implementation Plan (ILOIP) Annex 02: Support Launch Team (SLT) Firing Room Seating Plan	JICB	GSDO-C2088-X	Update to incorporate errata	Artemis I, Artemis II, Artemis III, Artemis IV	JICB	Coordination	9/1/2023	Operations Integration	
GSDO-PLN-1129	Artemis I, Artemis II, Artemis III, Artemis IV	Cross-Program Integrated Launch Operations Implementation Plan (ILOIP)	JICB	GSDO-C2126-X	Update to incorporate errata	Artemis I, Artemis II, Artemis III, Artemis IV	JICB	Coordination	9/1/2023	Operations Integration	
GSDO-PLN-1145	Artemis I, Artemis II	EGS Program-to-Orion MPCV Program Bilateral Software Hardware Exchange Agreements, Lists and Schedules	JICB	GSDO-D2282-X	Per Program Management Direction, monthly "Straight to Directives" will be completed to update agreed data changes, withdrawn items, and closed items. In addition, the Board may be asked to approve new items for inclusion into the document or other clean-up as described.	Artemis I, Artemis II	JICB	Board	6/28/2023	CPIT	Agreements
GSDO-PLN-1154	Artemis I, Artemis II	EGS-to-Orion MPCV Program Bi-lateral Data Exchange Agreements, Lists, and Schedules (BDEALS)	JICB	GSDO-D2283-X	Per Program Management Direction, monthly "Straight to Directives" will be completed to update agreed data changes, withdrawn items, and closed items. In addition, the Board may be asked to approve new items for inclusion into the document or other clean-up as described.	Artemis I, Artemis II	JICB	Board	6/28/2023	CPIT	Agreements

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Orion Artemis I Open Change Requests Report: Combined Configuration Management Report and Performance to Plan Report (Wiki)



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Product Number	Product Mission Effectivity	Product Title	Product Board	CR Number	Description of Change	CR Mission Effectivity	CR Approval Board	Lifecycle	Lifecycle Date	Functional Area	ITT
MPCV 70156	NFS	Cross Program Fluid Procurement and Use Control Specification	JICB	MPCV-2415-X	Minor Changes to MPCV 70156 - revised specification for HFE7200 MPCV coolant, changed specification for MPCV internal coolant to identify required coolant composition (procurement and as delivered to flight hardware interface).	NFS	JICB	Board	7/19/2023	System Analysis and Integration	Integrated Propulsion and Fluids
MPCV 72542	Artemis I, Artemis II	Cross Program Engineering Imagery Concept of Operations (ConOps)	JICB	MPCV-2449-X	Update MPCV 72542 Cross Program Engineering Imagery Concept of Operations (ConOps) to Revision F This is a Limited-Scope CR. Reviewers are asked to limit their reviews to the changes cited in the CR, and only the contents that have been modified. The CR SME reserves the right to reject the comments that do not fall within the scope of this review. Edits include: Document now sunsets after Artemis II; Additional MO for CM de-servicing/disassembly (existing capability);Deletes Goals for Gateway and HLS (now covered in ACD document);TBD deletions from Rev E (Gateway and HLS Goals/MOs now covered in ACD document)	Artemis I, Artemis II	JICB	Board	7/27/2023	System Engineering	Imagery
MPCV 72575	Artemis I, Artemis II	Orion Multi-Purpose Crew Vehicle (MPCV) Program-to-Space Launch System Program (SLSP), & Flight Operations Directorate (FOD), Bilateral Data Exchange Agreements, Lists, and Schedules (BDEALS)	JICB	MPCV-2461-X	Per Program Management Direction, monthly "Straight to Directives" will be completed to update agreed data changes, withdrawn items, and closed items. In addition, the Board may be asked to approve new items for inclusion into the document or other clean-up as described.	Artemis I, Artemis II, Artemis III, Artemis IV	JICB	Board	9/29/2023	CPIT	Agreements
MPCV 72568	Artemis I, Artemis II, Artemis III, Artemis IV	Orion Multi-Purpose Crew Vehicle (MPCV) Program-to-Space Launch System Program (SLSP) & Flight Operations Directorate (FOD), Bilateral Software Hardware Exchange Agreements, Lists and Schedules (BSHEALS)	JICB	MPCV-2462-X	Per Program Management Direction, monthly "Straight to Directives" will be completed to update agreed data changes, withdrawn items, and closed items. In addition, the Board may be asked to approve new items for inclusion into the document or other clean-up as described.	Artemis I, Artemis II, Artemis III, Artemis IV	JICB	Board	9/29/2023	CPIT	Agreements

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SLS Artemis I Open Change Requests Report: Combined Configuration Management Report and Performance to Plan Report (Wiki)



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Product Number	Product Mission Effectivity	Product Title	Product Board	CR Number	Description of Change	CR Mission Effectivity	CR Approval Board	Lifecycle	Lifecycle Date	Functional Area	ITT
SLS-RQMT-040-	Artemis I, Artemis II, Artemis III, Artemis IV, Artemis V, Artemis VI, Artemis VII, Artemis VIII, Artemis IX	Space Launch System Program (SLSP) Electromagnetic Environmental Effects (E3) Requirements	SLS SICB	SLS-01183	Revise SLS-RQMT-040, SLSP Electromagnetic Environmental Effects (E3) Requirements to Revision K	NFS	SLS SICB	Coordination	7/21/2023	System Analysis and Integration	E3
SLS-HDBK-118-05	Artemis I	Cross-Program Flight Operations Handbook (FOH) Volume 5: Interim Cryogenic Propulsion Stage (ICPS)	JICB	SLS-01200-X	Revise SLS-HDBK-118-05, Cross-Program Flight Operations Handbook (FOH) Volume 5: Interim Cryogenic Propulsion Stage (ICPS) to Revision B	Artemis I	JICB	Coordination	9/25/2023	Operations Integration	Flight Techniques Panel
SLS-HDBK-291	Artemis I, Artemis II, Artemis III	Cross-Program SLS Vehicle Condition Imagery Document	JICB	SLS-01209-X	Revise SLS-HDBK-291, Cross-Program SLS Vehicle Condition Imagery Document, to Revision B	Artemis I, Artemis II, Artemis III	JICB	Coordination	9/21/2023	System Engineering	
SLS-RPT-207-01	Artemis I, Artemis II, Artemis III	Cross-Program Integrated Vehicle Envelope and Deflection Report Volume 1: Block 1	JICB	SLS-01217-X	Updating 207-01 to Rev C Updates include: 1. Update VSP shimming values in section 3 and reference JLT presentation. Attach this presentation into the appendix in a new section. 2. Update the Booster aft strut section to include the revised numbers as determined during the Artemis-I WDR and launch attempt. 3. Update the excursions in Section 4 with the MAC2A loads. 4. Update the umbilical excursions in Section 5 with the MAC2A loads. 5. Include Core Stage II aft strut pinning assessment in the appendix.	Artemis I, Artemis II	JICB	Coordination	7/21/2023	System Analysis and Integration	Integrated Drawing Management
SLS-RPT-147-01	Artemis I	Cross-Program Flight Termination System Report (FTSR) Volume 1: Artemis I Mission	JICB	SLS-01225-X	This report provides the roadmap for the Ranges Safety item in the Elements and Program post flight report. It also identifies documents that were updated prior to Artemis I launch that had previously been submitted.	Artemis I	JICB	Coordination	8/17/2023	Operations Integration	Range Safety
SLS-RQMT-045-01	Artemis I, Artemis II, Artemis III	Cross-Program Vehicle Design Environments Integrated Vehicle Loads Volume 1: SLS Block 1	JICB	SLS-01227-X	SLS-RQMT-045-01 Rev E to Rev F: 1) Add APPENDIX G SLS BLOCK 1 CREW ARTEMIS II MAC2A LOADS 2) Address previous Hanging Directives 3.) SLS B1 ARII MAC2A loads being incorporated into 045.	Artemis I, Artemis II, Artemis III	JICB	Coordination	8/4/2023	System Analysis and Integration	Loads

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Configuration Management Lessons Learned



- **What went well on Artemis I:** Open communication and collaboration within the Information Configuration Management Working (ICMWG) to facilitate the exchange of ideas and guidelines for sharing communication created an environment allowing for the:
 - Successful distribution, review, reporting, tracking and management of approximately 6000 Cross Program Change Requests for Artemis I
 - Development of business principles to document cross program integration guidelines (i.e., metadata fields, participation in meetings, etc.)
- **Best Practice:** Continue open communication and collaboration as M2M processes are developed further across all programs
- **Lesson Learned:** Additional Performance-to-Plan reporting was required to provide data status and burn-down plan to support Cross Program Strategic Integration readiness;
 - ICMWG gathered requirements to provide Performance-to-Plan reporting capability within the configuration management tool by updating the tool metadata and creating reports for the specific need
- **Lesson Learned:** Continue to gather and implement reporting requirements for Artemis II and future reporting needs



Back-Up



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Artemis I PFAR

Orion

July 19-20, 2023

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Orion Vehicle Integration Office
Jim Geffre

Agenda



Day 1 PM – Domestic Portion

- Mission Overview and Performance Summary
- Flight Test Objective (FTO) and Developmental FTO Metrics
- In-Flight Anomalies
- Lessons Learned
- Domestic Special Topics

Day 2 AM – International Portion

- International Special Topics
- Success Criteria Evaluation
- Summary and Forward Work

Special Topics	
Domestic	Heatshield Char Loss
	CM/SM R&R Separation Bolt Condition Post-Flight
	CMA PAA1 Performance Degradation
	External Acoustic Environment Exceedances
International	PCDU LCL Off Anomaly
	SM Fuel Panel (Bridgewire Checks)
	RTV Application Improvements
	PDU Soft Reset Anomaly



Mission Overview and Performance Summary

Mission Highlights

- During the mission 161 Flight Test Objectives and Developmental Flight Test Objectives were performed.
 - On May 12 Orion [post flight analysis of FTO and DFTO report](#) complete
- The mission went smoothly enough to add 21 Real-Time DFTOs during the mission on top of the pre-planned 17 DFTOs.
- The SAWs generated more power than predicted.
- Power consumption was less than predicted, primarily due to lower heater need.
- Attitude control maneuvers didn't need as much prop as predicted.
- The EDL sequence went well. The total skip downrange was around 3100 nmi. All 11 parachutes deployed. Orion landed 2.1 nmi from the predicted target, well within uncertainty bounds. All 5 CMUS bags deployed and stayed inflated.
- The mission was a great success!

Mission Review Background



- Orion flew November 16 - December 11th.
 - During the 25.5 days the team analyzed real-time telemetry and available downlinked RPMs. Items for investigation (IFI) were noted for unexpected system performance needing further investigation post flight.
 - Available TPM and downlinked RPM data was stored in Ops History during the flight and continued to be read into Ops History after the flight. Issues in data access led to parallel path for all TPM/RPM data also to be stored at JSC/FSL/Mach5.
- [Matlab-ingestible DFI files](#) were available between 1/25-2/8
- Feb 1-2 Orion held an initial [lessons learned and early mission review meeting](#).
 - Mission review primarily based on in flight assessments of system performance.
 - March 1st, Orion gave a 1 hour summary of the [lessons learned and mission review status](#) to JICB.
- April 12, Orion post flight analysis pencil's down
- April 27-28, Orion [pencil's down data review](#) to identify issues and expectations for the FTO/DFTO final report.
- May 12, Orion [post flight analysis of FTO and DFTO report](#) complete.
- June 15, Updated mission review status at [PFAR milestone](#) includes all updates known

